



Death in the line of duty...

Fire Fighter Suffers a Fatal Heart Attack During a Training Exercise – Michigan

SUMMARY

On April 23, 2001, a 58-year-old male volunteer fire fighter participated in a search-and-rescue training exercise. Wearing full turnout gear, including self-contained breathing apparatus (SCBA) with a black cover on the face piece (to simulate impaired visibility), he and another fire fighter were attempting to locate a “victim” (a training mannequin) in an area of the fire station. After they searched one room and moved to the next, the ill fire fighter said that he had to get out. He sat up against the wall, where others helped him remove his helmet and face piece. He soon stopped breathing. Despite immediate cardiopulmonary resuscitation (CPR) and advanced life support (ALS) performed on the scene by crew members, medical first responders, and paramedics, and by hospital personnel in the emergency department, the fire fighter died. Based on findings at autopsy, the death certificate, completed by the Medical Examiner, listed “acute myocardial infarction” as the immediate cause of death and “arteriosclerotic cardiovascular 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 represent published research, consensus votes of technical committees of the National Fire Protection Association (NFPA), or fire service labor/management groups.

- *Depending on the applicant's age and coronary artery disease (CAD) risk factors,*

include exercise stress testing (EST) in the preplacement medical evaluation.

- *Institute a periodic medical evaluation program. This program should incorporate EST, depending on the fire fighter's age and CAD risk factors.*
- *Fire fighters should be medically cleared for respirator use by a physician knowledgeable about the physical demands of fire fighting and the personal protective equipment used by fire fighters.*
- *Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.*

INTRODUCTION AND METHODS

On April 23, 2001, a 58-year-old male fire fighter died after collapsing during a training exercise. On April 24, 2001, the United States Fire Administration notified NIOSH of the death. On August 13, 2001, NIOSH contacted the affected Fire Department to initiate the investigation. On October 8, 2001, a

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



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

People interviewed included the

- Fire Chief
- Assistant Chief for the deceased fire fighter's fire station
- Crew members on duty with the deceased fire fighter
- Deceased fire fighter's spouse and daughter
- City's risk manager
- Deceased fire fighter's physician

Documents reviewed included

- Fire Department policies and operating guidelines
- Deceased fire fighter's training records
- Fire Department annual report for 2000
- Fire Department medical evaluation records
- Deceased fire fighter's medical records maintained by his private physician
- Ambulance response report
- Hospital emergency department records
- Fire Department incident report
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

Incident. On April 23, 2001, the affected fire fighter attended a training meeting at Fire Station #5. The meeting started at 1900 hours, but his exact arrival time was not determined. He and 19 other volunteer fire fighters were scheduled to participate in a simulated search-and-rescue training exercise. In teams of two, wearing full turnout gear, including self-contained breathing apparatus (SCBA), they attempted to locate and rescue a "victim" (a training mannequin) in one of two rooms located off a hallway leading to the apparatus bay. To simulate reduced visibility due to smoke, their face pieces had a black cloth cover. The affected fire fighter was part of the second team; they finished donning their gear and

began the exercise shortly after 2000 hours. The team was observed by a crew member feeding hose near the door to the apparatus bay and by another (the exercise organizer) who was near the door to the second room.

The training exercise required the fire fighters to move on their hands and knees while pulling a charged fire hose. The affected fire fighter was behind his partner, feeding hose as his partner searched the first room. He said that his knees hurt, but mentioned no other symptoms then or later. They moved to the second room (where the mannequin was); after his partner had entered the room and located the mannequin, he heard the affected fire fighter, who was at the doorway, say that he had to get out. The ill fire fighter then sat up against the hallway wall and apparently attempted to remove his face piece, but his helmet strap prevented this. His partner and one of the observing fire fighters helped him get his helmet and face piece off, noting that the supplied air was flowing. They observed him to be sweating and breathing hard. One of them asked him if he was all right and he nodded, seeming to indicate that he was. His eyes then glazed over and he stopped breathing. This was estimated to have been about 5 minutes after the exercise began. One of the fire fighters notified the Assistant Chief, who radioed dispatch for medical assistance. (Shortly afterward, another crew member phoned 911 for medical assistance.)

A crew member who was a paramedic came to help. He found the collapsed fire fighter lying down, cyanotic (blue), apneic (not breathing), and pulseless. He started CPR but found the hallway too constraining, so the fire fighters moved the collapsed fire fighter to the apparatus bay (which took only a few seconds) and CPR was resumed. The medical first responders arrived 2 to 3 minutes later and continued CPR. Paramedics arrived shortly afterward and instituted ALS. After 12 minutes at the fire station, they transported the collapsed fire



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fighter to the hospital, a trip of 2 minutes, arriving about 2030 hours. Resuscitation efforts at the fire station included two shocks (both unsuccessful) for ventricular fibrillation. Resuscitation efforts, including another attempt at defibrillation, continued in the emergency department without success, and the fire fighter was pronounced dead at 2051 hours.

Medical Findings. The death certificate, completed by the Medical Examiner, listed "acute myocardial infarction" as the immediate cause of death and "arteriosclerotic cardiovascular disease" as the underlying cause.

Pertinent findings from the autopsy report, completed by the Medical Examiner, are listed below:

- Acute Myocardial Infarction due to Arteriosclerotic Cardiovascular Disease with Acute sub-epicardial antero-lateral myocardial infarction.
- Coronary atherocalcinosis with maximal manifestation and 75% luminal stenosis in left mid descending coronary artery.
- Cardiomegaly with dilated cardiomegaly and left ventricular hypertrophy ...”

The deceased fire fighter was a manager at a data services company. He retired 2 years prior to his death. Among his activities since retirement was the development of a computer program for the fire department to keep track of the volunteer fire fighters; he did this work at his fire station. He played golf regularly, and in the weeks before his death he walked the course instead of riding in a golf cart. He did yard work and other home maintenance activities. He never mentioned symptoms of CAD to his family or crew members. His fire station had no calls in the 24 hours preceding his death. On the day of his death, he played golf in the morning and seemed in good spirits the rest of the day.

The deceased fire fighter took medication (a statin) for hypercholesterolemia. He took aspirin daily as heart attack prophylaxis. He took medication for high blood pressure in the past but not since 1990. Because his blood pressure was not consistently high in recent years, his physician did not prescribe anti-hypertensive medication for his "borderline hypertension." He weighed 206 and 200 pounds, respectively, at the time of his 1972 and 1976 preplacement physical examinations. His medical records indicated a range of 195 to 219 pounds in recent years. At autopsy, he weighed 227 pounds, was 71 inches tall, and thus had a body mass index (BMI) of 32 kg/m^2 . (A BMI above 30 kg/m^2 indicates obesity.¹) His father had a (nonfatal) heart attack at age 58.

The deceased fire fighter's last Fire Department medical evaluation was in 1986 when he rejoined after returning from living out of state for 4 years. An EST in April 1999 was normal [13.5 metabolic equivalents (MET) at 10 minutes, heart rate 162 (99% of target)]. In December 1999, he was cleared for respirator use on the basis of a respiratory questionnaire and pulmonary function tests. His last general checkup by his personal physician was in December 2000.

DESCRIPTION OF THE FIRE DEPARTMENT

The Fire Department consists of 13 salaried uniformed personnel (all administrative) and 170 volunteer fire fighters. It serves a population of 81,000 residents in a geographic area of 34.6 square miles. There are six fire stations. In 2000, the Department responded to 1,333 calls: 220 fires and 1,113 other calls. The fires included 90 structure fires, 72 vehicle fires, 22 grass fires, 22 refuse fires, and 14 outside structure fires. The other calls included 350 good intent, 286 false alarms, 220 system malfunctions, 179 hazardous conditions, 35 public service, and



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43 rescues/extrications. The station to which the deceased fire fighter was assigned responded to 126 calls. The Fire Department does not respond to calls for medical assistance; these are handled by a contract ambulance service, which provides both medical first response and paramedic services.

Training. To qualify as a fire fighter, an applicant must pass a medical evaluation (discussed below) and physical agility test. Successful applicants are assigned probationary status, during which they must complete the Michigan Fire Fighters Training Council Fire Fighter I and II program, attend at least 60 hours of training per year, and respond to at least 50% of the station responses for which they are available. In addition to his fire fighter levels I and II training, the deceased fire fighter had driver/operator and operations-level hazardous materials (HAZMAT) training. He had been a volunteer fire fighter continuously since 1972, except for 1 year in the 1980s, when he lived in a city without a volunteer fire department. All but 3 years of his fire fighting experience were with the Fire Department described in this report. He has held various positions/ranks in this Department, including Assistant Chief; his current rank was Lieutenant.

Periodic Evaluations. Except for the 25-30 HAZMAT personnel, periodic fitness-for-duty medical evaluations are not required or provided by the Fire Department. Medical clearance for respirator use is required every 2 years; this clearance is provided by a mobile health screening clinic and is apparently based on a respiratory questionnaire and pulmonary function tests. A volunteer who is injured or becomes ill, whether work-related or not, must be cleared to return to work as a fire fighter by both a personal physician and the medical clinic serving as the Fire Department physician. There are no “light duty” assignments available. If the illness or injury is work-related, the person is entitled to benefits,

including compensation for inability to perform the usual (non-fire fighting) job.

The fire stations have exercise equipment available for fire fighters. The Department does not have a mandatory exercise/fitness program. The deceased fire fighter was not known to use the exercise equipment at his fire station. In 1997, the Department provided a voluntary health promotion evaluation (76 of 170 fire fighters participated). Individual results were sent to the participant; the FD received a summary of the program’s findings but no information regarding specific individuals. Another such effort is planned.

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 In addition to his age and gender, the deceased fire fighter had four of the other seven risk factors: family history of CAD, high blood cholesterol, high blood pressure, and obesity/overweight.

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. Although the deceased fire fighter’s autopsy report identified “75% luminal stenosis in left mid descending coronary artery,” no thrombus was identified.



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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.^{7,8} Sudden cardiac death is often the first overt manifestation of ischemic heart disease.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 deceased fire fighter, wearing full turnout gear, pulled a charged fire hose while moving through the training site on his hands and knees; this would be considered relatively heavy work, requiring 6-7 MET.^{15, 19-21}

The Fire Department requires a preplacement medical evaluation for all applicants but, except for HAZMAT personnel, no general periodic medical evaluations. (A limited biannual evaluation is required for respirator clearance.) The preplacement evaluation differs from the National Fire Protection Association (NFPA) Standard 1582, *Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*,²² in that neither audiology nor EST is included. Also, lumbar spine X-rays are included, even though this procedure is not mentioned in NFPA 1582. NFPA 1582 recommends a brief medical evaluation annually and

a more extensive evaluation periodically according to the age of the fire fighter (less than 30: every 3 years; 30-39: every 2 years; over 40 years: every year). NFPA 1582 recommends EST for fire fighters over the age of 35 with risk factors for CAD and for all fire fighters over age 40.

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.²³

²⁴ Despite these problems, NFPA 1582 nevertheless recommends EST for fire fighters without risk factors for CAD beginning at age 40.²² Other expert groups do not recommend EST for asymptomatic individuals without risk factors for CAD.²⁵⁻²⁷

When these asymptomatic individuals have risk factors for CAD, recommendations vary by organization. NFPA recommends biannual EST for fire fighters with CAD risk factors beginning at age 35.²² For medical certification for the commercial drivers 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.²⁵ 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.²⁸ 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/



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efficacy is less well established by evidence/opinion” (as opposed to the “weight of evidence/opinion [being] in favor of usefulness/efficacy.”²⁶

- 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, 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 criteria for Groups 1 and 4.

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).²⁷ The USPSTF indicates that there is insufficient evidence 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.”²⁷

A number of other noninvasive (that is, not requiring cardiac catheterization) diagnostic procedures have been proposed to evaluate CAD. These include (1) tests for silent and inducible ischemia, and (2) tests of atherosclerotic burden. The first group includes, in addition to EST, exercise and pharmacological stress echocardiography, exercise and pharmacological myocardial perfusion imaging, ambulatory ECG monitoring, and positron emission tomography. A 1998 conference sponsored by the American Heart Association (AHA) concluded that, with the exception of EST for men with CAD risk factors, there are insufficient data to support the use of these tests for screening asymptomatic people.²⁹ The second group of procedures includes ankle/brachial blood pressure index (ABI), carotid artery B-mode ultrasound imaging, electron beam computed tomography (EBCT), magnetic resonance imaging, endothelial function studies, and high sensitivity testing for C-reactive protein. The AHA-sponsored conference concluded that the last three procedures are not yet ready for general use, that ABI might be useful in people over age 50 with other risk factors, that carotid B-mode ultrasound can add information to the risk factor assessment in asymptomatic people over age 45, and that EBCT, which measures coronary artery calcification and produces a coronary calcium score, may be of use in “the detection of advanced coronary atherosclerosis in patients at apparently intermediate risk” but “should not be recommended for routine risk assessment in asymptomatic populations.”²⁹ A subsequent American College of Cardiology/AHA consensus document, which reviewed more recent studies of EBCT, concluded that “although preliminary data are intriguing with respect to risk prediction in the asymptomatic patient, available data are insufficient to support recommending EBCT to asymptomatic members of the general public or for routine clinical use.”³⁰ The document does not address the use of EBCT for screening occupational groups. A recent cardiology textbook described



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EBCT as “not more diagnostic” of CAD than EST.”³¹

The deceased fire fighter had an EST 2 years before his heart attack; it did not show any evidence of CAD. Whether a more recent EST would have identified CAD is an open question. His hypercholesterolemia was controlled by medication, and he was at least moderately physically active on a regular basis. Although he had borderline hypertension, his blood pressure readings in recent years would be considered acceptable by NFPA 1582.²² His physician had recommended that he lose weight and engage in nonimpact aerobic exercise. It is possible that a health promotion program that included more vigorous exercise and weight control might have helped prevent his fatal heart attack.

RECOMMENDATIONS AND DISCUSSION

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 represent published research or consensus votes of Technical Committees of the National Fire Protection Association, or fire service labor/management groups.

Recommendation #1: Depending on the applicant’s age and coronary artery disease (CAD) risk factors, include exercise stress testing (EST) in the preplacement medical evaluation.

NFPA 1582, *Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians*, and the International Association of Fire Fighters/International Association

of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative both recommend EST for fire fighters.^{22,32} 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.

The current preplacement evaluation should also be modified to include audiometry, and back X-rays should be discontinued as a routine screening procedure. NFPA 1582 and the IAFF/IAFC wellness/fitness initiative recommend audiometry for fire fighters.^{22,32} Lumbar spine X-rays may be useful in the evaluation of individuals with existing back problems, but they have not been shown to be of value as a routine screening procedure for job applicants. The anatomical abnormalities they identify are common and poorly predictive of subsequent back injury, pain, or lost work time.³³⁻³⁸ The American College of Occupational and Environmental Medicine recommends that lumbar spine X-rays not be done as a routine screening procedure.³⁹ If used for this purpose, a lumbar spine X-ray entails both an unnecessary radiation exposure for the applicant and an unnecessary expense for the Fire Department.

Recommendation #2: Institute a periodic medical evaluation program. This program should incorporate EST, depending on the fire fighter’s age and CAD 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 1582.²² 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.



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Although a program of periodic medical evaluations involves considerable expense, especially to a relatively large department, this expense is offset by the savings accrued by having a department composed of volunteers rather than paid fire fighters.

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 8-7.2.⁴⁰ 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 retain fire fighters.

Recommendation #3: Fire fighters should be medically cleared for respirator use by a physician knowledgeable about the physical demands of fire fighting and the personal protective equipment used by fire fighters.

The medical evaluation for respirator use should involve considerations beyond respiratory symptoms and pulmonary function testing (PFT).⁴¹⁻⁴³ Although pulmonary status needs to be considered, cardiac health is a more important factor in determining

whether a fire fighter is medically fit to use SCBA with turnout gear. The primary physiological burdens are the added weight of the air bottle and other turnout gear and the heat load resulting from the fire, exertion, and turnout clothing. Thus, the medical evaluation for respirator clearance depends more on the medical history (of which a symptom questionnaire can be part) and physical examination than on PFT. PFT may be useful for evaluating respiratory symptoms or physical examination findings, but it is otherwise not needed routinely for a respirator clearance evaluation. Many workers, however, including fire fighters, have periodic PFT for other reasons, and the results should obviously not be ignored.

Recommendation #4: 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.⁴⁰ 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.³² 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



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work-related injuries and lost work days.^{44,45} 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.

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