F2000
34
NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation *December 12, 2000*

Lieutenant Dies at a Fire in a One-and-One-Half Story Dwelling - West Virginia

SUMMARY

On April 26, 2000, a 43-year-old male Lieutenant suffered a cardiac arrest at the scene of a fire in a 1½-story single-family dwelling. After a loose connection on his self-contained breathing apparatus (SCBA) caused the Lieutenant to lose air, he exited the structure to change air cylinders. While his air cylinder was being changed, he collapsed. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) performed on the scene by crew members and paramedics, and by hospital personnel at the emergency department (ED), the victim died 8 days later. The death certificate, completed by the Assistant Medical Examiner, listed "atherosclerotic coronary disease" as the immediate cause of death. An inspection report, also completed by the Assistant Medical Examiner, listed "myocardial infarct (based on circumstances, EKG changes, and serologic testing)" as the cause of death and "mild chronic obstructive pulmonary disease and hepatitis per history" 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, consensus votes of technical committees of the National Fire Protection Association (NFPA), or fire service labor/management groups. In addition, the recommendations are presented in a logical programmatic order and are not listed in a priority manner. Issues relevant to this Fire Department include

- ***Mandatory preemployment medical evaluations consistent with NFPA 1582 should be conducted to determine a candidate's medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Fire fighters should have mandatory annual medical evaluations and periodic physical examinations to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.***
- ***Exercise stress tests should be incorporated into the Fire Department's medical evaluation program.***
- ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

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. 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:

http://www.cdc.gov/niosh/firehome.html

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

- ***Provide fire fighters with medical evaluations and determination of clearance to wear self-contained breathing apparatus (SCBA).***

- ***Provide adequate fire fighter staffing to ensure safe operating conditions.***

INTRODUCTION AND METHODS

On May 4, 2000, 8 days after suffering a cardiac arrest while fighting a structure fire, a 43-year-old male Lieutenant died. On July 31, 2000, NIOSH contacted the affected Fire Department to initiate the investigation. On August 9, 2000, a Safety and Occupational Health Specialist and a physician from the NIOSH Fire Fighter Fatality Investigation Team traveled to West Virginia to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel interviewed the following:

- Fire Chief
- Union representative
- Crew members on duty with the victim
- Ambulance service paramedics
- Victim's wife

During the site visit NIOSH personnel reviewed

- Fire Department policies and operating guidelines
- Fire Department training records
- Fire Department annual report for 1999
- Fire Department physical examination protocols
- Ambulance response report
- Hospital records
- Past medical records of deceased from private physician
- Autopsy report

INVESTIGATIVE RESULTS

Incident. On April 26, 2000, the victim reported for work at 0800 hours. The day was spent performing equipment checks and station maintenance. At 1551 hours, E911 dispatched the involved Fire Department to a fire in a 1½- story, wood-frame, single- family dwelling with cinder block basement. Engine 1 (victim and two Fire Fighters), Engine 3 (two Fire fighters), Truck 6 (service unit, two Fire Fighters), and Unit 10 (one Fire Inspector [Captain]) responded. Ambulance 808 (two paramedics) also responded. Units began to arrive on the scene at 1554 hours. Heavy smoke was visible on three sides and on both levels of the structure, and with flame visible inside the first floor. The victim and a Fire Fighter, wearing full turnout gear and self-contained breathing apparatus (SCBA), stretched a 1½- inch hoseline to the front door. Two additional Fire Fighters, wearing full turnout gear and SCBA, met them at the front door. Initial fire attack was initiated through the front door by the three Fire Fighters. The victim remained outside to check for fire extension. A positive-pressure ventilation (PPV) fan was placed at the front door to begin ventilation of the structure. After knockdown was accomplished in the living room and kitchen area of the first floor, the crew proceeded to the second floor. The victim and the Captain, wearing full turnout gear and breathing air from their SCBAs, stretched a 1¾-inch hoseline into the first-floor area. The Fire Chief arrived on the scene at 1606 hours and assumed command at 1608 hours. The Captain and a Fire Fighter were extinguishing hotspots in the kitchen and living room when the Captain heard what he thought was a burst hose. As the victim walked beside the Captain, the Captain realized the sound was the victim's SCBA. The Captain stopped the victim and tightened his SCBA regulator connection. The victim connected his regulator hose to his facepiece and informed the Captain that he was out of air and was going to change his air cylinder. Once outside, the victim advised the Chief that he had a problem with

his SCBA's air supply and was going to get a new cylinder. The victim proceeded to Engine 1 and bent down so his SCBA cylinder could be changed. The Driver/Operator (D/O) of Engine 1 asked the victim what he needed. The victim looked over his shoulder and said "air bottle," then collapsed.

The D/O thought the victim had passed out. He rolled the victim over and took his facepiece off as an EMT assessed the victim. The EMT requested the medical bag and oxygen and called the on-scene EMS Chief to assess the victim. As the EMS Chief began to assess the victim, the victim stopped breathing. Further assessment revealed the victim was unresponsive and pulseless. Cardiopulmonary resuscitation (CPR, chest compressions and assisted ventilations via bag valve mask) was initiated as the on-scene ambulance crew was notified. The ambulance crew arrived at the victim's location, and again the victim was found to be unresponsive, not breathing, and pulseless. A cardiac monitor revealed ventricular fibrillation (V.Fib.). A total of six electrocardioversions (shocks) were delivered on the scene. After the last shock, the victim's heart rhythm reverted to pulseless electrical activity (PEA). CPR continued throughout, the victim was intubated, intravenous medications were administered, and ACLS protocols were followed. The victim was loaded into the ambulance, which departed the scene at 1620 hours. The ambulance arrived at the hospital emergency department (ED) at 1622 hours.

Inside the ED, CPR and ALS continued. A cardiac monitor revealed V.Fib., seven additional electrocardioversions (shocks) were administered, and a pulse was regained at 1652 hours. At this time, the victim was responsive to painful stimuli and to plantar stimulation (rubbing the soles of the feet), and his eyes reacted to light. Initial medical diagnosis consisted of the following: (1) given his recent two-week history of chest pains, acute myocardial ischemia leading to ventricular fibrillation and arrest, and (2) anoxic encephalopathy (lack of oxygen to the brain) due to being in V.Fib. for an extended period of time and developing pulmonary edema. Blood gases drawn twice within the first hour in the ED revealed carboxyhemoglobin (blood carbon monoxide) levels of 1.3% and 1.9%, suggesting the victim was not exposed to significant levels of carbon monoxide. Subsequent serial electrocardiograms (EKGs), blood tests (serum troponin levels), and echocardiograms confirmed the occurrence of a myocardial infarction (heart attack) in the anteroseptal and inferior regions. Due to the victim's grave prognosis, invasive medical tests and interventions were discontinued on April 29. Over the next 4 days, the victim's condition deteriorated. On May 4, at 2250 hours, an examination revealed that the victim had stopped breathing and was pulseless. At 2325 hours, the victim was pronounced dead by the attending physician.

Medical Findings. The death certificate, completed by the Assistant Medical Examiner, listed "atherosclerotic coronary disease" as the immediate cause of death.

Medical records indicated that the victim had four coronary artery disease (CAD) risk factors: male gender, smoking, family history, and high cholesterol. He had complained to his wife of chest pain occurring while he performed work and of being tired for the two-week period prior to his heart attack, but he did not seek medical attention. There was no record of the victim having taken an exercise stress test (EST).

A visual inspection, rather than an autopsy, was also completed by the Assistant Medical Examiner. Based on this inspection, the following "pathologic diagnosis" was listed:

- "Myocardial infarct (based on circumstances, EKG changes, and serologic testing)"

- "Mild chronic obstructive pulmonary disease and hepatitis per history."

Medical records did not reveal a physical examination since 1978. However, laboratory tests conducted in December 1995 and June 1996 revealed elevated cholesterol levels. Medical records did not indicate whether the victim was prescribed medication or specific preventive measures to lower his cholesterol level. An electrocardiogram (EKG) performed following a medical procedure in 1998 revealed palpitations, premature atrial contractions (PACs), and premature ventricular contractions (PVCs). He was referred to his private physician who performed a medical evaluation, which revealed a history of smoking, occasional episodes of asthma, and consumption of 10-12 cups of coffee daily, but no chest discomfort. He had used a nasal spray the morning of the procedure. The physician determined that either the nasal spray or the coffee consumption could have caused palpitations and probably PVC's, and no further evaluation at that time was needed.

The victim had worked a 24-hour shift 2 days prior (April 24) and responded to an apartment fire in a two-story apartment building at 0740 hours on April 25. Engine 1, Engine 2, Engine 3, Truck 5, Service Truck 6, Unit 8, and Unit 10 responded, a total of 18 personnel. At this fire, the victim, wearing full turnout gear and SCBA, on air, entered the structure and assisted in fire extinguishment. The fire was knocked down within approximately 20 minutes, after which time the victim, who was going off shift, left the scene. He went home and prepared to go to his part-time job of computer maintenance. While at home, he mentioned to his wife that he did not feel well. He worked at his part-time job from 0845 hours until 1730 hours. That evening, he gave a presentation to the City Council regarding budget cuts and Fire Department staffing. He had been under stress for some time regarding this issue. On April 26, the day of his collapse, the victim reported to the Fire Department for work as usual. Throughout the day, he performed station maintenance and equipment checks. According to crew members, he looked pale most of the day. The fire at which he collapsed was his only emergency response during his shift on April 26.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Fire Department consisted of 27 uniformed career personnel and served a population of 12,000 residents in a geographic area of 8 square miles. There are two fire stations. Fire fighters, including the victim, work on one of three shifts, are on a 24-hour shift from 0800-0800 hours and work an average of 56 hours weekly on a 3-week schedule. An example follows: Week 1: Sunday, Thursday, and Saturday; Week 2: Monday and Wednesday; Week 3: Tuesday and Friday.

In 1999, the Department responded to 1,462 calls: 59 structure fires, 42 brush, grass, and trash fires, 16 vehicle fires, 5 mutual-aid calls, 736 rescue calls, 168 motor-vehicle accidents, 139 good-intent/ smoke-scare calls, 118 false alarms, 99 hazardous-condition calls, and 80 service calls.

Training. The Fire Department requires all new fire fighters to pass a preemployment physical examination, a timed physical-agility test, and a written civil-service test. Each applicant is ranked based on a combined score from the physical-agility test and the written civil-service test. A new hire is selected from the top three scorers. An applicant not selected within three hiring cycles is removed from the selection list. Once hired, the fire fighter must complete the state-mandated Fire Fighter I training (if not already certified), which is given at the Fire Department. An additional 16-40 hour orientation training is given, depending on the new

hire's level of knowledge and experience. CPR and First- Aid training are required before entering a hazardous area. Hazardous Materials (Hazmat) training is given at the operations level. Once recruit training is completed, the Fire Fighter is assigned to a shift. Subsequent training is conducted on shift. The State requires fire fighters to complete apprenticeship training, a 6,000-hour course which includes a minimum of 240 hours during the first year of work. At the end of 3 years, the Fire Fighter is required to pass the apprenticeship test. There is no state requirement for annual fire-fighter recertification, although there is for Hazmat and CPR. The victim was certified as a Fire Fighter II, Driver/Operator, Hazmat, and Fire Inspector, and had 21 years of fire-fighting experience.

Preemployment/Preplacement Evaluations. The Department requires a preemployment/preplacement medical evaluation for all new hires, regardless of age. Components of this evaluation for all applicants include the following:

- Physical examination
- Blood tests: Complete Blood Count (CBC), Metabolic Profile, and Lipid Profile
- Chest X-ray
- LS Spine X-ray
- Urine Tests: Urine dip stick, VDRL, and Urine Drug Screen
- Audiometry
- Vision test: distant and near vision

These evaluations are performed by the new hire's private physician, and the results are reviewed by two physicians (state requirement), city contract physicians. Once this evaluation is complete, the reviewing physicians make a determination regarding medical clearance for fire-fighting duties and forward this decision to the City's personnel director.

Periodic Evaluations. This department does not require periodic medical evaluations. A voluntary annual physical examination is offered by the City and is paid for by the City's insurance carrier. Approximately 50% of Fire Department personnel participate, but the results of each examination are not forwarded to the City physicians or the Fire Department. The victim's last Fire Department medical examination was in 1978, when he was hired. According to records available to NIOSH, no abnormalities were noted, and he was cleared for fire-fighting duties. If an employee is injured at work or ill, the employee is evaluated and must be cleared for "return to work" by his or her private physician.

Although all fire stations have exercise (strength and aerobic) equipment, primarily purchased by the Fire Department, the Department does not have a mandatory fitness program. No wellness programs (smoking cessation, weight control, high blood pressure, diabetes, or cholesterol) are offered by the City.

DISCUSSION

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[1] Risk factors for its development include increasing age, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes.[2] The victim had several of these risk factors (male gender, smoking, family history, and high cholesterol).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[3] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[4] 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.[5] This sudden

blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. Less than 50% of heart attack victims have a thrombosis at autopsy. The autopsy in this case did not indicate if a thrombosis was present or not, but it did list "myocardial infarct (based on circumstances, EKG changes, and serologic testing)" and "mild chronic obstructive pulmonary disease and hepatitis per history" as the cause of death.

Blood clots, or thrombus formation, in coronary arteries are 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.[5] 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.[6,7]

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[8] 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.[9-11] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[12-15] The victim had advanced 1½-inch and 1¾-inch hoselines and was performing interior fire spread search activities while wearing full turnout gear with SCBA (weighing approximately 50-60 pounds total), and breathing air from the SCBA. This is considered a moderate level of physical exertion.

The Department requires a preemployment/ preplacement medical examination for all new hires but does not require periodic medical evaluations. NFPA recommends a yearly physical evaluation to include a medical history, height, weight, blood pressure, and visual acuity test.[16] NFPA also recommends a thorough examination to include vision testing, audiometry, pulmonary function testing, a complete blood count, urinalysis, and biochemical (blood) test battery be conducted on a periodic basis according to the age of the fire fighter (less than 30, every 3 years; 30 to 39, every 2 years; over 40 years, every year).

To reduce the risk of heart attacks and sudden cardiac arrest among fire fighters, the National Fire Protection Association (NFPA) has developed guidelines entitled "Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians," otherwise known as NFPA 1582.[16] They recommend, in addition to screening for risk factors for CAD, an exercise stress electrocardiogram (EKG), otherwise known as an exercise stress test (EST). The EST is used to screen individuals for 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 angina), young men, and women.[17,18] This has led other expert groups to **not** recommend EST for asymptomatic individuals without risk factors for CAD.[19,20]

When these asymptomatic individuals **have** risk factors for CAD, however, recommendations vary by organization. The American College of Cardiology/American Heart Association (ACC/ AHA) identifies four groups for EST although they note that the "usefulness/efficacy is less well established by evidence/opinion."[19]

- Group 1: Persons with multiple risk factors. They define five risk factors for CAD: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic greater than 140 mm Hg or diastolic greater than 90

mm Hg), smoking, diabetes, and family history of premature CAD (cardiac event in 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 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).[20]

The USPSTF indicates that evidence is insufficient to recommend screening middle-age and older men or women in the general population; however, "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety."[20]

The victim had complained to his wife of chest pains and of feeling tired for 2 weeks before his collapse but did not seek medical attention. Crew members did not report any recent episodes of chest pains or any other symptoms of pain or discomfort, but they did report that the victim was under stress from budget and staffing reductions.

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 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 National Fire Protection Association or labor/management groups within the fire service. In addition, they are presented in a logical programmatic order and are not listed in a priority manner.

Recommendation #1: Mandatory preemployment medical evaluations consistent with NFPA 1582 should be conducted to determine a candidate's medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

The Fire Department currently performs preemployment physical evaluations which include routine lumbar spine X-rays. While these X-rays may be useful in the evaluation of individuals with existing problems, the American College of Radiology, American College of Occupational and Environmental Medicine, and NIOSH all have concluded that lumbar spine X-rays have no value as a routine screening measure to determine those at risk for back injuries.[21,22] This procedure involves both an unnecessary radiation exposure for the applicant and an unnecessary expense for the Department. Guidance regarding the content of preemployment medical evaluations for fire fighters can be found in NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians,[16] and in the report of the International Association of Fire Fighters/ International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative.[23]

Recommendation #2: Fire Fighters should have mandatory annual medical evaluations and periodic physical examinations 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 for fire fighters can be found in 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.[16,23] As mentioned in the discussion section above, EST are a recommended component of the periodic evaluation.

Recommendation #3: Exercise stress tests should be incorporated into the Fire Department's medical evaluation program.

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 at least biannual EST for fire fighters.[16,23] They recommend that these tests begin at age 35 for those with CAD risk factors and at age 40 for those without CAD risk factors. The EST could be conducted by the fire fighter's personal physician (at City or Fire Department expense) or the City physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the City physician, who is responsible for decisions regarding medical clearance for fire-fighting duties.

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.[24] In 1997, 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.[23] Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[25,26] 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.[27]

Recommendation #5: Provide fire fighters with medical evaluations and determination of clearance to wear self-contained breathing apparatus (SCBA).

The Occupational Safety and Health (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection.[28] These clearance evaluations are required for private-industry employees and public employees in States operating OSHA-approved State plans. Since West Virginia is not a State-plan State, public- sector employers are not required to comply with OSHA standards. However, we recommend following this standard. A copy of the OSHA medical checklist has been provided to the Fire Department. Compliance with the standard should not involve a financial burden to the Fire Department beyond that required for the fitness-for-duty medical evaluation.

Recommendation #6: Provide adequate fire-fighter staffing to ensure safe operating conditions.

Typically, an Engine is staffed with less than four personnel and the Ladder is staffed with four personnel. However, due to sick leave and vacations, apparatus staffing often falls to three personnel or less. NFPA 1500 recommends a minimum of four fire fighters be present where only one team (company) is operating in the hazardous area at a working structural fire, two individuals working as a team in the hazard area and two individuals present outside this hazard area for assistance or rescue.[24] This could be accomplished by any of the following: (1) increasing the number of fire fighters assigned to a company, (2) hiring fire fighters to act as "floaters" to fill in positions vacated by employees who are sick or who are on vacation, (3) staggering vacation days in conjunction with hiring floating fire fighters. The basis for this standard is improvement of worker safety while fighting interior structural fires.

REFERENCES

1. Fauci AS, Braunwald E, Isselbacher KJ, et al. [1998]. Harrison's principles of internal medicine. 14th ed. McGraw-Hill: New York, pp. 222-225.

2. American Heart Association (AHA) [1998]. AHA scientific position, risk factors for coronary artery disease. Dallas, TX.

3. Fauci AS, Braunwald E, Isselbacher KJ, et al. [1998]. Harrison's principles of internal medicine. 14th ed. McGraw-Hill: New York, p. 1348.

4. Shah PK [1997]. Plaque disruption and coronary thrombosis: new insight into pathogenesis and prevention. Clin Cardiol *20*(11 Suppl2):II-38-44.

5. Fuster V, Badimon JJ, Badimon JH [1992]. The pathogenesis of coronary artery disease and the acute coronary syndromes. N Eng J Med *326*:242-250.

6. Kondo NI, Muller JE [1995]. Triggering of acute myocardial infarction. J Cardiovasc Risk *2*(6): 499-504.

7. Opie LH [1995]. New concepts regarding events that lead to myocardial infarction. Cardiovasc Drug Ther *9*(3)(Suppl):479-487.

8. Gledhill N, Jamnik, VK [1992]. Characterization of the physical demands of firefighting. Can J Spt Sci *17*(3):207-213.

9. Barnard RJ, Duncan HW [1975]. Heart rate and ECG responses of fire fighters. J Occup Med *17*:247-250.

10. Manning JE, Griggs TR [1983]. Heart rate in fire fighters using light and heavy breathing equipment: simulated near maximal exertion in response to multiple work load conditions. J Occup Med *25*:215-218.

11. Lemon PW, Hermiston RT [1977]. The human energy cost of fire fighting. J Occup Med *19*:558-562.

12. Willich SN, Lewis M, Lowel H, et al. [1993]. Physical exertion as a trigger of acute myocardial infarction. N Eng J Med *329*:1684-1690.

13. Mittleman MA, Maclure M, Tofler GH, et al. [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Eng J Med *329*:1677-1683.

14. Siscovick DS, Weiss NS, Fletcher RH, Lasky T [1984]. The incidence of primary cardiac arrest during vigorous exercise. N Eng J Med *311*:874-877.

15. Tofler GH, Muller JE, Stone PH, et al. [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the Thrombolysis in Myocardial Infarction Phase II (TIMI II) Study Group. J Am Coll Cardiol *20*:1049-1055.

16. National Fire Protection Association [2000]. NFPA 1582, standard on medical requirements for fire fighters and information for fire department physicians. Quincy, MA: National Fire Protection Association.

17. Michaelides AP, Psomadaki ZD, Dilaveris PE, et al. [1999]. Improved detection of coronary artery disease by exercise electrocardiography with the use of right precordial leads. New Eng J Med *340*:340-345.

18. Darrow MD [1999]. Ordering and understanding the exercise stress test. American Family Physician. January 15, 1999.

19. Gibbons RJ, Balady GJ, Beasley JW, Bricker JT, Duvernoy WFC, Froelicher VF, Mark DB, Marwick TH, McCallister BD, Thompson PD, Winters WL Jr, Yanowitz FG [1997]. ACC/AHA guidelines for exercise testing: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). J Am Coll Cardiol *30*:260-315.

20. U.S. Preventive Services Task Force [1996]. Guide to clinical prevention services. 2nd ed. Baltimore, MD: Williams & Wilkins, pp. 3-15.

21. Present AJ [1974]. Radiography of the lower back in pre-employment physical examinations: conclusions of the ACR/NIOSH Conference, January 11-14, 1973. Radiology *112*:229-230.

22. ACOEM [1979]. Use of routine X-ray examinations in occupational medicine. [http://www.acoem.org/paprguid/guides/xray.htm].

23. International Association of Fire Fighters and International Association of Fire Chiefs [1997]. The fire service joint labor management wellness/fitness initiative. Washington, D.C.: International Association of Fire Fighters, Department of Occupational Health and Safety.

24. National Fire Protection Association [1997]. NFPA 1500, standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association.

25. National Institute of Consulting Services, 1996.

26. Maniscalco P, Lane R, Welke M, Mitchell J, Husting L [1999]. Decreased rate of back injuries through a wellness program for offshore petroleum employees. J Occup Environ Med *41*:813-820.

27. City Auditor, City of Phoenix, AZ. Disability retirement program evaluation. January 28, 1997.

28. 29 CFR 1910.134. Code of Federal Regulations. Occupational Safety and Health Administration: Respiratory Protection. Washington, D.C.: National Archives and Records Administration, Office of the Federal Register.

INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by Tommy N. Baldwin, MS, Safety and Occupational Health Specialist, and Ilza Jekabsone, MD, Visiting Scientist. Mr. Baldwin is with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component, located in Cincinnati, Ohio. Dr. Jekabsone was a NIOSH guest researcher at the time of the investigation.