2009
16
NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation *October 2009*

Lieutenant Suffers a Fatal Cardiac Event After Completing Live Fire Training - Wisconsin

SUMMARY

On December 8, 2008, a 42-year-old Lieutenant (LT) in a Volunteer Fire Department (FD) died after completing live fire training drills that were part of a certified Fire Fighter II training course. The live fire training involved two separate drills: 1) extinguishing a simulated natural gas fire, and 2) discharging a foam line. The LT complained of cold symptoms during the training and became short of breath during the last evolution. Upon completion of the last drill, as other students cleaned up the hose lines, he indicated that he was going to his FD vehicle to rest. Approximately 10 minutes after leaving the training area, the LT was found pulseless, breathless, and non-responsive in the area between the training site and his FD vehicle. Cardiopulmonary resuscitation (CPR) was initiated by firefighters followed by advanced life support (ALS) by the arriving ambulance personnel. Despite these efforts the LT died. The autopsy report listed the cause of death as "Cardiac arrhythmia following strenuous physical activity (firefighter training) in individual with hypertensive and atherosclerotic cardiovascular disease." NIOSH investigators agree with this assessment and conclude that the physical exertion associated with the training drills performed in full personal protective equipment triggered the LT's sudden cardiac death.

NIOSH investigators offer the following recommendations to reduce the risk of fatalities from sudden cardiac arrest among fire fighters at this and other fire departments across the country. Had these recommended measures been in place prior to the FF's collapse, his sudden cardiac death may have been prevented at this time.

- ***Ensure that an automated external defibrillator is available during planned training drills.***
- ***Provide on-scene emergency medical services with advanced life support and transport capability during live fire training.***
- ***Provide mandatory pre-placement and periodic medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) Standard 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.***
- ***Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.***

- ***Develop a comprehensive wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease (CVD) and improve cardiovascular capacity.***
- ***Discontinue lumbar spine x-rays as a screening test administered during the pre-placement medical evaluation.***

INTRODUCTION & METHODS

On December 8, 2008, a 42 year old LT collapsed and died after completing live fire training. Despite on-scene CPR, defibrillation, and ALS, the LT could not be revived. The United States Fire Administration notified NIOSH of this fatality on December 9, 2008. NIOSH contacted the affected FD shortly thereafter to obtain further information, and again on July 22, 2009, to schedule the investigation. On August 17, 2009, a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) conducted an on-site investigation of the incident.

During the investigation, the NIOSH investigator interviewed the following people:

- Fire Chief
- Instructor in charge of the training drills
- Battalion Chief of responding FD
- Paramedics responding to the LT
- Crew members who were involved in training with the LT
- LT's wife

The NIOSH investigator reviewed the following documents in preparation of this report:

- Dispatch records
- Ambulance report
- Death certificate
- Autopsy report
- Primary care physician's medical records
- Police report of the fatality
- Crew members' statements
- FF training records
- Fire Department 2008 Annual Report

RESULTS OF INVESTIGATION

Community College Fire Training Center. The fire training center, a State-accredited training facility, provides live fire training to firefighters from a two-county area. The training facility offers live fire training that leads to Fire Fighter I and II Certification. The training center also offers a number of other fire service courses as part of an Associates Degree program. The Fire Fighter II course that the LT was taking involved 40 hours of classroom and live fire instruction. The class met once a week for 4 hours (1800 – 2200 hours) with the live fire drill on December 8, being the final class of the course.

Prior to this incident, no major event such as burn injuries or cardiac arrests had occurred during training programs at the facility. The administrator in charge of the program report-

ed that several minor cuts and sprains have occurred during training over the years, but only one injury (a knee sprain) was serious enough to warrant transport to the Emergency Department.

Incident. On December 8, 2008, the LT awoke at approximately 0600 hours and worked a full day (about 0800 to 1630 hours) at his full-time job as a phone installer, which required moderate levels of physical activity. He spoke with his wife by telephone twice in the afternoon and reported no medical complaints. Following work, the LT drove approximately 30 miles to the training facility with three other firefighters from the area who were also enrolled in the Firefighter II course. The group stopped and had dinner prior to attending the class.

The class met in a classroom at the training facility at 1800 hours to review the drills of the evening. At approximately 1830 hours the class went outside to conduct training drills. It was snowing lightly and the temperature was approximately 35 °F, with 81% humidity, and winds out of the southeast at 11.5 mph [Weather Underground 2009]. The training involved two separate exercises: one which simulated a natural gas fire at a gas station, and the second which involved setting up a "foam line." The students were involved in training from approximately 1830 hours until 2018 hours when the incident occurred.

The simulated natural gas fire drill involved a crew of three firefighters advancing an 1¾" hose line to suppress a natural gas fire and turning off the gas supply. Each team completed the drill three times with each FF serving in the three positions on the line. During these drills the FFs wore full personal protection equipment and self contained breathing apparatus (SCBA). Each drill lasted approximately 1-2 minutes. The drill was described as moderately strenuous by students and instructors. When students were not performing the drill they were watching other students. After each evolution the entire group critiqued each performance. The LT performed all three rotations of his team's drill with no reduction of his physical performance, no complaints, and no appearance of distress.

The foam drill entailed setting up and discharging a 1¾" foam line. A bucket of foam concentrate was positioned next to the engine and an "eductor" was used to take up the foam concentrate, aerate it, and mix it with water. The class opened the nozzle on the line to discharge the foam and observed the "foam blanket" that was created. There was no fire suppression involved in this drill and only one evolution was performed by the LT's team. The drill was described as very light by the instructors and fellow students. While other teams were performing the drill, one of the instructors and some of the students noticed the LT catching his breath with his hands on his knees. Although the LT successfully completed the drill the instructor questioned the LT about his condition. The LT reported that he had been suffering from a cold for the last week and that the natural gas fire drill had "kicked his butt." Despite noting these symptoms, instructors and other classmates did not consider the LT's condition to be serious because his symptoms

seemed relatively mild, they did not affect his drill performance, and they seemed to be plausibly explained by his recent cold.

Following the foam drill, the training was completed for the evening. The instructor instructed the students to pack up the equipment and return to the classroom. The LT told a fellow FF and an instructor that he was going back to his FD vehicle to catch his breath while the others students finished cleaning up.

Approximately 8-10 minutes later, students and instructors from the class noticed the LT lying face-up on the ground approximately 50-75 ft from his vehicle. The LT was still dressed in full turnout gear lying on top of his SCBA. The LT was unresponsive, pulseless, and not breathing. Classmates immediately began CPR and an instructor called 9-1-1 and requested an ALS ambulance. Prior to the ambulance arrival, a police officer at the training facility provided an automated external defibrillator (AED) from his squad car to firefighters performing CPR. The AED was attached to the LT but no shock was advised (at least two cycles of checking the AED resulted in no shock messages). Fellow firefighters in the class continued CPR until care was transferred to the arriving paramedic unit.

The 9-1-1 call was received at 2018 hours and an ALS ambulance arrived on-scene approximately 6 minutes later (2024 hours). Upon arrival the paramedics found the LT unresponsive, pulseless, and not breathing with CPR in progress. Paramedics were unable to intubate the LT, therefore oxygen was provided by bag-valve mask with adequate ventilation documented by end tidal carbon dioxide measurements. At this point the AED reported that the LT was in asystole (no heart beat). An intravenous (IV) line was placed and epinephrine and atropine were administered and the heart rhythm temporarily converted to ventricular fibrillation. A shock was administered, but the heart rhythm quickly returned to asystole and remained in asystole or pulseless electrical activity for 30 minutes. Approximately 50-55 minutes after the LT collapsed, the physician providing medical control to the ambulance team advised that ALS should be discontinued. At 2104 hours the LT was pronounced dead.

Medical Findings. A Forensic Pathology Fellow in the County Medical Examiner's Office performed the autopsy and completed the death certificate. The death certificate and autopsy listed "cardiac arrhythmia following strenuous physical activity (firefighter training) in individual with hypertensive and atherosclerotic cardiovascular disease" as the immediate cause of death. Evidence of atherosclerotic disease included approximately 50% stenosis of the right coronary and left anterior descending artery. Evidence of hypertensive cardiovascular disease included moderate to marked left ventricular hypertrophy. For more complete autopsy information see appendix A.

The LT was 69 inches tall and weighed 186 pounds, giving him a body mass index (BMI) of 27.5. A BMI of 25.0–29.9 kilograms per meters squared (kg/m2) is considered overweight [CDC 2009]. The LT was reportedly conscientious about his diet, and a waist cir-

cumference of 32 inches suggested that he did not have abdominal obesity. He was active in his work (phone installer) but he did not exercise regularly. The LT was a non-smoker.

The LT's last medical evaluation was in February 2008 when he obtained a yearly physical from his primary care physician. At that time his blood pressure was normal [122/70 millimeters of mercury (mmHg)], his glucose was slightly elevated [101 milligram per deciliter (mg/dL)] as was his cholesterol (209 mg/dL)]. A review of his medical records revealed several instances of high blood pressure readings in 2003 and 2004 (144/88; 140/84, 132/86; 140/90), however, these readings were obtained when he was seeing his physician for medical reasons such as a cold or joint pain that could have been responsible for a temporary rise in his blood pressure. Furthermore, all blood pressure readings obtained by his physician since March 2004 were normal.

The LT had had a cold for several weeks, which he had been treating with over-the-counter medication, and he expressed to several people during training that he thought the cold was responsible for his fatigue and difficulty breathing during the training.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Volunteer FD consisted of one fire station with 46 uniformed personnel (Paid Call) that served a population of approximately 3,300 residents in a geographic area of just over a square mile. In 2008, the FD responded to 582 alarms of which 24 were fire calls.

Membership and Training. The FD applicants must be at least 18 years of age and have a high school diploma. All applicants go through an interview process with the Fire Chief and a line officer. As part of their employment contract, candidates are required to indicate their acceptance of the duty requirements (including attending at least 65% of training and responding to a minimum of 20% of fire calls). New members undergo an orientation program that includes reviewing response guidelines, working in dispatch, and being mentored by a line officer. Candidates are required to pass a physical agility test, but members do not have this requirement. The LT had been a member of the FD for over 16 years and was promoted to the rank of Lieutenant in May 2008. The LT was a certified Firefighter I, Driver/Operator-Pumper, and Emergency Medical Technician. He had also completed training in Extrication, HazMat Recognition, Fire Arson Detection, Incident Command System, and National Incident Management System.

Medical Evaluation Program. The FD requires a pre-employment medical evaluation for new members. The pre-employment medical evaluation includes a respirator questionnaire (consistent with one required for the Occupational Safety and Health Administration (OSHA) respiratory protection standard (CFR 1910.134)], physical examination, lumbar spine x-ray, blood chemistries, urinalysis, and urine drug screen. The FD has no requirement

for annual medical evaluations for continuing members. The department collects survey information about a change in health status each year. Injured members must submit a notice of restriction from their primary care physician and provide documentation from their physician that they are cleared to return to work.

Health and Wellness Programs. The FD does not offer a formal health and wellness program although a Employee Assistance Program is offered through the Village. No fitness program is offered.

DISCUSSION

Cardiovascular Disease. In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male sex, family history of CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. Despite the fact that the LT had no established risk factors for CAD, he had moderate CAD at autopsy.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. 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 [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques.

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the LT's case, he did not have a heart rhythm on which to conduct an EKG; cardiac enzymes were not tested due to his death prior to cardiac enzymes becoming positive (> 4 hours); and no coronary artery thrombus was found at autopsy. During his training exercise he expressed symptoms consistent with, but not diagnostic of, a heart attack While it is possible the LT suffered a heart attack, it is unlikely given the autopsy findings.

A more likely cause of the LT's sudden cardiac death is a primary cardiac arrhythmia. On autopsy the LT was found to have left ventricular hypertrophy and cardiomegaly. Both conditions independently increase the risk of cardiac arrhythmias and sudden death [Levy et al. 1990; Novo et al. 1997; Haider et al. 1998]. Although the mechanism(s) by which cardiac hypertrophy increase the risk for sudden cardiac events is not fully understood, it is known that left ventricular hypertrophy reduces coronary blood flow reserve while increasing myocardial oxygen consumption. This imbalance may lead to ischemia, arrhythmias, and sudden cardiac death [Haider et al. 1998].

Epidemiological studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart at-

tacks and sudden cardiac death [Siscovick et al. 1984; Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. The LT had participated in live-fire training while wearing full personal protective equipment and an SCBA. Firefighting training is considered moderate to heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Fire fighters involved in training are at increased risk of sudden death due to coronary heart disease. [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. Given the LT's underlying CAD (noted at autopsy), the physical stress of performing fire fighting training duties probably triggered a cardiac arrhythmia or a heart attack, resulting in his sudden cardiac death.

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the LT was found to have left ventricular hypertrophy as indicated by a left ventricular wall measuring 1.8 cm and a slightly enlarged heart (430 grams). These finding were not identified prior to his death. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The LT did not have a documented history of high blood pressure, had no heart valve problems, and did not appear to have ischemic heart disease. Therefore, it is unclear why the LT had left ventricular hypertrophy and cardiomegaly. Although the EKG is not a very sensitive screening test for LVH, it is possible that if one had been performed his LVH would have been identified and additional evaluation and treatment been performed [Okin et al. 1996].

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 [NFPA 2007a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation, and medical fitness for duty criteria. This FD requires preplacment medical evaluations, but does not require annual medical evaluations for members.

Physical Fitness Programs for Structural Fire Fighters. The National Volunteer Fire Council (NVFC) and the U.S. Fire Administration (USFA) Health and Wellness Project document Health and Wellness Guide was developed to improve health and wellness within the volunteer fire service [USFA 2004]. This guide provides suggestions for successfully implementing a health and wellness program for volunteer fire departments. The LT's fire department did not have a physical fitness program.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to reduce the risk of fatalities from sudden cardiac arrest among fire fighters at this and other fire departments across the country. Had these recommended measures been in place prior to the FF's collapse, his sudden cardiac death may have been prevented at this time.

Recommendation #1: Ensure that an automated external defibrillator (AED) is available during all planned training drills.

The major determinants of survival after a sudden cardiac arrest are the initiation of cardiopulmonary resuscitation (CPR) and rapid defibrillation [Bayes de Luna 1989; Cobb et al., 1999; Page et al., 2000; Capucci et al. 2002]. Firefighters initiated CPR immediately upon discovering the LT's body but his collapse was not witnessed and it is estimated that 8-10 minutes may have elapsed before he was discovered. The fire training center did not have an AED available on site. A police officer was on the campus when the call was dispatched and arrived on scene in approximately 2 minutes with an AED. Hence, it is unlikely that having an AED on-scene would have changed the outcome in this case. However, given the improvement in survival rates with the prompt use of an AED, it is recommended that an AED be readily available at all planned training drills.

Recommendation #2: Provide on-scene emergency medical services with advanced life support and transport capability during live fire training.

NFPA 1403 requires an ambulance and emergency medical personnel be on scene during all live fire exercises. It defines emergency medical services as "the provision of treatment, such as first aid, CPR, basic life support, advanced life support, and other pre-hospital procedures including ambulance transportation, to patients." These EMS personnel must remain on scene until all exercises are concluded, equipment is restored to an in-service condition, and students are released [NFPA 2007c].

The fire training center does not have an ambulance, and the closest emergency medical transport unit and advanced life support unit was 6 minutes away. However, since the LT was down an estimated 8-10 minutes before being discovered, it is unlikely that on-scene advanced life support and/or transport would have changed the outcome in this case.

Recommendation #3: Provide mandatory annual medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) Standard 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

The NFPA 1582 Standard is designed to determine a firefighter's medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others [NFPA 2007a]. Adopting this standard can be particularly difficult for small volunteer fire departments because of the cost associated with implementation. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [USFA 2004; NFPA 2007b].

To overcome the financial obstacle of medical evaluations, the FD could urge current members to get annual medical clearances from their private physicians. Another option is hav-

ing the annual medical evaluations completed by paramedics and emergency medical technicians (EMTs) from the local EMS system (vital signs, height, weight, visual acuity, and electrocardiogram [EKG]). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the FD, City, or State. Sharing the financial responsibility for these evaluations between fire fighters, the FD, the City, the State, and physician volunteers may reduce the financial obstacles and facilitate implementation of this Standard.

Recommendation #4: Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000]. According to these guidelines, the Fire Department should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007b]. The physician should review job descriptions and essential job tasks required for all Fire Department positions and ranks, in order to understand the physiological and psychological demands of firefighting and the environmental conditions under which firefighters perform, as well as the personal protective equipment they must wear during various types of emergency operations.

Recommendation #5: Develop a comprehensive wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease (CVD) and improve cardiovascular capacity.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the NVFC's Health and Wellness Guide [IAFF, IAFC 2000; USFA 2004; NFPA 2008a]. These guidelines provide information to reduce risk factors for cardiovascular disease and improve cardiovascular capacity. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, reducing the number of work-related injuries, and reducing the number of work-related lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted

by the Oregon Health and Science University reported a savings of over one million dollars for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non occupational healthcare costs [Kuehl 2007]. Given this fire department's structure, the NVFC program might be the most appropriate model. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #6: Discontinue lumbar spine x-rays as a screening test administered during the pre-placement medical evaluation.

The FD currently performs pre-placement physical evaluations, which include routine lumbar spine X-rays. While these X-rays may be useful in evaluating individuals with existing problems, a number of organizations and researchers have concluded that lumbar spine X-rays have no value as a routine screening measure to determine risk for back injuries [Present et al. 1974; Gibson et al. 1988; Waddell et al. 2001]. This procedure involves both an unnecessary radiation exposure for the applicant and an unnecessary expense for the FD.

REFERENCES

AHA [2000]. Advanced cardiovascular life support: section 3: adjuncts for oxygenation, ventilation, and airway control. Circ 102(8)(Suppl):I-95–I-104.

AHA [2008]. AHA scientific position, risk factors for coronary artery disease. Dallas, TX: American Heart Association. [http://www.americanheart.org/presenter.jhtml?identifier=4726]. Date accessed: August 2008.

AIHA [1971]. Ergonomics guide to assessment of metabolic and cardiac costs of physical work. Am Ind Hyg Assoc J 32(8):560–564.

Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE [2000]. Triggering of sudden death from cardiac causes by vigorous exertion. N Engl J Med 343(19):1355-1361.

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot 15(5):296–320.

Bayes de Luna A, Coumel P, Leclercq JF [1989]. Ambulatory sudden cardiac death mechanisms of production of fatal arrhythmia on the basis of data from 157 cases. Am Heart J. 117: 151–159.

Blevins JS, Bounds R, Armstrong E, Coast JR [2006]. Health and fitness programming for fire fighters: does it produce results? Med Sci Sports Exerc 38(5):S454.

Capucci A, Aschieri, D, Piepoli MF, Bardy GH, Iconomu E, Arvedi M [2002]. Tripling Survival From Sudden Cardiac Arrest Via Early Defibrillation Without Traditional Education in Cardiopulmonary Resuscitation. Circ. 106:1065-1070.

CDC (Centers for Disease Control and Prevention) [2009]. BMI – Body Mass Index. [www.cdc.gov/nccdphp/dnpa/bmi/adult_BMI/english_bmi_calculator/bmi_calculator.htm]. Date accessed: August 2009.

Cobb LA, Fahrenbruch CE, Walsh LTR, Copass MK, Olsufka M, Breskin M, Hallstrom AP [1999]. Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out-of-hospital ventricular fibrillation. JAMA. 281:1182–1188.

Dempsey WL, Stevens SR, Snell CR [2002]. Changes in physical performance and medical measures following a mandatory firefighter wellness program. Med Sci Sports Exerc 34(5):S258.

Fuster V, Badimon L, Badimon JJ, Chesebro JH [1992]. The pathogenesis of coronary artery disease and the acute coronary syndromes. N Engl J Med 326(4):242–250.

Gibson ES [1988]. The value of pre-placement screening radiography of the low back. Occup Med 3(1):91-107

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

Haider AW, Larson MG, Benjamin EJ, Levy D [1998]. Increased left ventricular mass and hypertrophy are associated with increased risk for sudden death. J Am Coll Cardiol 32: 1454-1459.

IAFF, IAFC [2000]. The fire service joint labor management wellness/fitness initiative. 2nd ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ health: a global access science source. 2:14. [http://www.ehjournal.net/content/2/1/14]. Date accessed: September 10, 2008.

Kales SN, Soteriades ES, Christophi CA, Christiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. N Engl J Med 356(12):1207–1215.

Kuehl K [2007]. Economic Impact of the Wellness Fitness Initiative. Presentation at the 2007 John P. Redmond Symposium in Chicago, IL on October 23, 2007.

Levy D, Garrison RJ, Savage DD, Kannel WB, Castelli WP [1990]. Prognostic implications of echocardiographically determined left ventricular mass in the Framingham Heart Study. N Engl J Med 323(24):1706–1707.

Libby P [2008]. The pathogenesis, prevention, and treatment of atherosclerosis. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1501–1509.

Meyerburg RJ, Castellanos A [2008]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1707–

1713.

Mittleman MA, Maclure M, Tofler GH, Sherwood JB, Goldberg RJ, Muller JE [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Engl J Med 329(23):1677–1683.

NFPA [2007a]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

NFPA [2007b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

NFPA [2007c]. Standard on live fire training evolutions. Quincy, MA: National Fire Protection Association. NFPA 1403.

NFPA [2008a]. Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association. NFPA 1583.

NFPA [2008b]. Standard on the rehabilitation process for members during emergency operations and training exercises. Quincy, MA: National Fire Protection Association. NFPA 1584.

NIOSH [2007]. NIOSH alert: preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007-133.

NOAA [2008]. Quality controlled local climatological data. National Oceanic and Atmospheric Administration. [http://cdo.ncdc.noaa.gov/qclcd/QCLCD]. Date accessed: December 2008.

Novo S, Barbagallo M, Abrignani MG, Nardi E, Ugo Di Maria U, Longo B1, Mistretta A, Strano A [1997]. Increased Prevalence of Cardiac Arrhythmias and Transient Episodes of Myocardial Ischemia in Hypertensives With Left Ventricular Hypertrophy but Without Clinical History of Coronary Heart Disease. Am J Hypertens. 10; 843–851.

Okin PM, Anderson KM, Levy D, Kligfield P [1996]. Heart rate adjustment of exercise-induced ST segment depression: improved risk in the multiple risk factor intervention trial. J Am Coll Cardiol 27:1437-43.

OSHA [2008]. State Occupational Safety and Health Plans. [www.osha.gov/fso/osp/index.html]. Date accessed: February 11, 2009.

Page RL, Joglar JA, Kowal RC, Zagrodzky JD, Nelson LL, Ramaswamy K, Barbera SJ, Hamdan MH, Mckenas DK [2000]. Use of automated external defibrillators by a US Airline. N Engl J Med. 26343: 1210–1216.

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.

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

Siegel RJ [1997]. Myocardial hypertrophy. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia,

PA: Lippencott-Raven, pp. 55–57.

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

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med 42(12):1148–1155.

Tofler GH, Muller JE, Stone PH, Forman S, Solomon RE, Knatterud GL, Braunwald E [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(5):1049–1055.

USFA [2004]. Health and wellness guide. Emmitsburg, MD: Federal Emergency Management Agency; United States Fire Administration. Publication No. FA-267.

USFA [2008]. Emergency incident rehabilitation. Emmitsburg, MD: Federal Emergency Management Agency; United States Fire Administration.

Waddell G, Burton AK [2001]. Occupational health guidelines for the management of low back pain at work: evidence review. Occup Med 2001;51:124-135.

Weather Underground [2009]. [http://www.wunderground.com/history/]. Accessed, September 22, 2009.

Willich SN, Lewis M, Lowel H, Arntz HR, Schubert F, Schroder R [1993]. Physical exertion as a trigger of acute myocardial infarction. N Engl J Med 329(23):1684–1690.

Womack JW, Humbarger CD, Green JS, Crouse SF [2005]. Coronary artery disease risk factors in firefighters: effectiveness of a one-year voluntary health and wellness program. Med Sci Sports Exerc 37(5):S385.

INVESTIGATOR INFORMATION

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Denise L. Smith, Ph.D, led the investigation and co-authored the report. Dr. Smith is professor of Exercise Science, and holds the Class of 1961 Chair at Skidmore College. She was working as a contractor with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component during this investigation. Thomas Hales, MD, MPH, provided medical consultation and coauthored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A

Autopsy Findings

- Hypertensive and atherosclerotic cardiovascular disease
- Moderate atherosclerostic stenosis, conronary arteries (50% atherosclerotic stenosis of right coronary artery and left anterior descending coronary arteries, and 30% stenoisis of the left circumflex coronary artery).
- Cardiac hypertrophy (heart weight = 430 grams)
- Moderate to marked left ventricular hypertrophy (left ventricle wall = 1.8 cm, right ventricle wall = .4 cm, septum = 1.1. cm)
- Slight arteriolonephrosclerosis
- Normal cardiac valves
- No evidence of a thrombus in coronary arteries
- No evidence of a thrombus or emboli in pulmonary arteries
- Blood tests for alcohol and illicit drugs were negative
- Microscopic examination of the cardiac tissue revealed slight myocyte hypertrophy