2008
19
NIOSH
Fire Fighter Fatality Investigation
and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation December 2008

Paid On Call Fire Fighter Suffers a Fatal Cardiac Event Just After Completing Two Hose Training Drills – Wisconsin

SUMMARY

On June 12, 2007, a 42-year-old paid on-call Fire Fighter (FF) participated in mandatory Fire Department training. The training involved hose drills consisting of making a hydrant connection, advancing an attack hose line, and utilizing the nozzle. The FF participated in two drills, each lasting about 5 to 10 minutes. There was a 15 minute "cool-down" period between drills during which time the FF removed his personal protective equipment, drank cool fluids, and helped reload the hose. Following a 15-20 minute break to discuss the goals of the training, the FF collapsed. Despite on scene cardiopulmonary resuscitation (CPR) and defibrillation, continued CPR in the ambulance, and advanced cardiac life support in the hospital Emergency Department, the FF could not be revived. The death certificate listed "acute, premature death" as the immediate cause of death and severe atherosclerotic disease and congenital hypoplasia of the right coronary artery as underlying causes, with multi-focal myocardial scarring and cardiomegaly as significant conditions contributing to the death. The autopsy was conducted by a faculty member at the nearby University School of Medicine and Public Health. The autopsy report concluded, "the comprehensive autopsy findings in conjunction with the clinical history support acute, premature cardiac death during work related strenuous physical activity." The NIOSH investigator considered that the physical effort associated with the hose drills performed during training in full personal protective equipment triggered a probable heart attack and the subsequent sudden cardiac death of this FF.

It is unclear if any of the following recommendations could have prevented the death of this FF at this time. Nonetheless, the NIOSH investigator offers the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters at this, and other, fire departments across the country.

- ***Provide mandatory pre-placement and period 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 (CVD) and improve cardiovascular capacity.***
- ***Ensure that incident scene rehabilitation is established for working fires and training evolutions.***

INTRODUCTION & METHODS

On June 12, 2007, a 42-year-old paid-on-call FF collapsed during departmental training drills. Despite on scene CPR and defibrillation, continued CPR en route and advanced cardiac life support in the hospital Emergency Department, the FF could not be revived. The United States Fire Administration notified NIOSH of this fatality on June 14, 2007. NIOSH contacted the affected Fire Department shortly thereafter to obtain further information, and again on August 1, 2008, to schedule the investigation. On August 11, 2008, 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
- Deputy Fire Chief
- Emergency Medical Technician responding to the FF
- Police detective who investigated the fatality
- FF's father (and fellow Fire Department member)
- Deputy coroner
- Co-worker from the FF's regular job

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

- Fire Department's Employers First Report of Injury or Disease
- Dispatch records
- Ambulance report
- Death certificate
- Autopsy report
- Primary care physician's medical records
- Hospital Emergency Department records
- Crew members' statements
- FF training records
- Fire Department standard operating guidelines
- Police statements about investigation

INVESTIGATIVE RESULTS

Incident Response. On June 12, 2007, the FF worked his usual job as a layout assistant for a surveying company. His coworker later reported that they took measurements and set posts (light to moderate work) and that the FF interacted with her in his normal fashion. It was a hot and humid day with maximal temperatures of 86 °F and 88% humidity. That evening the FF attended the regularly scheduled bimonthly Fire Department training drills.

Departmental training began at 18:30 hours at the fire station. After a short presentation by the Fire Chief (approximately 15-20 minutes), firefighters drove the fire apparatus to the training site (about 1.5 miles from the station). The evening training focused on hose work: making a hydrant connection, advancing an attack line, and utilizing a nozzle. The drills began at approximately 19:00 hours. At that time the temperature was 80.6 ºF and the relative humidity was 39% with winds out of the east at 8 miles per hour [Weather Underground 2008]. Each drill consisted of an Engine crew (four firefighters and an officer) making a hydrant connection with a 5" hose, completing a forward lay, and then using the stream from an 1 ¾" hoseline to move a 10 pound medicine ball across the opposing crew's line. A second Engine crew performed the same drill facing in the opposite direction. Drills were performed in full turnout gear and a self contained breathing apparatus (SCBA) and lasted between 5 to 10 minutes. Between drills FFs took off their helmets, hoods, and coat and were encouraged to drink water while they reloaded hose (about 15 minutes). The training was designed to improve:

- communication between officers and firefighters
- efficiency in making hydrant connections
- efficiency in advancing a charged 1 ¾" hose line, and
- nozzle control

There were three teams of four firefighters so not every firefighter participated in each drill. The "winner" of each drill stayed in the drill while the other team rotated out. The FF did not participate in the first drill, but then participated in two consecutive drills as the nozzleman back-up. After the second drill in which the FF participated, the entire group took a 15-20 minute break to discuss the goals of the drill. During this discussion the FF interacted normally. After the break, the firefighters were instructed to reload the hose on the engines for one final drill before the training ended. The FF and a fellow team member returned to their engine to shut down the hydrant and disconnect the 5" hose.

While preparing to disconnect the 5" hose from the engine, a fellow firefighter looked back toward the hydrant (approximately 100 ft away) and saw the FF lying on the ground. He estimated that it had been 1 to 2 minutes since he had last seen the FF walking toward the hydrant. The firefighter ran to where the FF was lying, found him unresponsive with labored breathing, and immediately radioed for help. Subsequent assessment by other firefighters on scene also found the FF unresponsive with shallow breathing and a weak pulse. Oxygen was provided via an adult bag-valve-mask as the FF's clothes were removed. Thinking heat strain may be involved, ice and wet towels were applied to cool the FF. Shortly thereafter, the FF lost his pulse and an automated external defibrillator (AED) was attached to the FF. A shock was advised and delivered with no change in his clinical status. CPR was initiated. After approximately 1 minute of CPR,

the AED indicated "shock advised" and another shock was given.

Emergency Medical Services (EMS) arrived on scene at 2016 hours. CPR was continued and the patient was switched over to the EMS defibrillator. EMS evaluation of the FF's cardiac rhythm advised another shock which was delivered two times with no change in the FF's clinical status. The FF was loaded onto a cot and then into the ambulance for transport to a nearby hospital (2021 hours). The total time that EMS treated the FF on scene was approximately 5 minutes.

En route to the hospital a breathing tube (combi-tube) was successfully placed into the FF's respiratory tract with placement confirmed by auscultation. The FF's heart rhythm was reanalyzed and another shock was delivered; again, there was no change in the FF's clinical status. CPR was continued until the ambulance arrived at the hospital (approximately 2023 hours).

In the hospital's Emergency Department, the FF was intubated, two intravenous lines were started and advanced life support (ALS) protocols were initiated. The FF briefly regained a pulse and independent breathing 25 minutes after arrival at the hospital but never regained consciousness. After an additional 52 minutes of resuscitation efforts in the Emergency Department, the FF was pronounced dead at 21:42 hours, approximately an hour and a half after his collapse.

Medical Findings. The death certificate listed "acute, premature death" as the immediate cause of death, and severe atherosclerotic disease and congenital hypoplasia of the right coronary artery as underlying causes leading to the event. The death certificate also noted multi-focal myocardial scarring and cardiomegaly as significant conditions contributing to the death. The autopsy was conducted by a faculty member at the nearby University School of Medicine and Public Health (see Appendix A). The autopsy report concluded, "the comprehensive autopsy findings in conjunction with the clinical history support acute, premature cardiac death during work related strenuous physical activity."

Prior to this episode, the FF was in good health and rarely visited a physician. He had few risk factors for CAD: he did not smoke, did not have diabetes mellitus, did not have high blood pressure, was not known to have high blood cholesterol, exercised regularly, and was not obese [the FF was slightly overweight according to body mass index (BMI) standards with a body mass index of 27.2 (normal BMI 20-25.0)] [CDC 2008]. However the FF did have a family history of early cardiovascular disease and death. The FF's last physical examination by a physician was on October 10, 2006. At this time the physician noted that the FF reported symptoms suggestive of heartburn.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the combination Fire Department consisted of 53 uniformed personnel (paid on call fire fighters

and 3 full-time chief officers). It has a single fire station, serves a population of approximately 14,000 residents, and covers an area of approximately 83 square miles. The Fire Department ran 216 calls in 2007, including nine structural fires.

Training. The Fire Department requires members to attend departmental training two evenings a month, typically conducted outdoors during the summer months. The FF was certified as a Firefighter II and as a Driver/Operator for aerial and pumper apparatus.

Pre-placement Medical Evaluations. The Fire Department currently requires that new members receive a medical examination (based on NFPA 1582) paid for by the Fire Department. However, this policy was not in place when the FF was hired in 1987.

Periodic Medical Evaluations. The Fire Department does not require periodic medical evaluations for fire fighters but does pay for voluntary annual medical examinations conducted by a Fire Department physician or nurse practitioner. Medical clearance for SCBA use is required; clearance is either done in conjunction with the medical examination, or for firefighters who do not complete a physical exam, the medical clearance is done at the Fire Department by personnel from the Occupational Health clinic. Fire fighters must be cleared by the Fire Department physician before returning to work after a serious injury and must be cleared by their own physician before returning to work after a serious illness. Other than his medical clearance for respirators, the FF did not have any medical evaluations conducted by the Fire Department. His last medical examination was in October of 2006 with his private physician.

Fitness/Wellness Programs. The Fire Department houses aerobic fitness equipment and since the death of the FF the volunteer Fire Fighters Association associated with the Fire Department has offered a voluntary training program with an extremely high participation rate.

DISCUSSION

CAD and the Pathophysiology of Sudden Cardiac Death. This FF experienced a cardiac arrest and sudden cardiac death following strenuous firefighting training. The most common risk factor for cardiac arrest and sudden cardiac death is coronary artery disease (CAD), defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2008]. The autopsy report confirmed that this FF had severe CAD with up to 90% blockage of one of the heart's major coronary arteries. There was also evidence of prior heart attacks in the form of multifocal cardiac scarring. Risk factors for CAD development include increasing age, male gender, family history of CAD, smoking, hypertension, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2008]. Given the extent and severity of the FF's CAD, it is surprising that the FF's only risk factors were male gender and family history.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2005]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Most heart attacks occur when a vulnerable plaque ruptures, causing a blood clot to form which occludes a coronary artery. Establishing the occurrence of an acute heart attack requires any of the following: characteristic electrocardiogram (EKG) changes, elevated cardiac enzymes, or coronary artery thrombus. The FF never regained a heart rhythm on which an EKG could reveal characteristic changes, he died before cardiac enzymes would become elevated, and no thrombus was found at autopsy. However, occasionally (16-27% of the time) post-mortem examinations do not reveal the coronary artery blood clots/plaque rupture during acute heart attacks [Davies 1992; Farb 1995]. The FF's significant CAD and the clinical scenario strongly suggest that the FF's death was due to a heart arrhythmia associated with a heart attack [Thaulow 1993; Libby 2005].

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding, requiring fire fighters to work at near maximal heart rates for long periods and causing significant physiological disruption [Barnard 1975; Lemon 1977; Manning 1983; Jankovic 1991; Smith 2001]. Even when energy costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulative properties of the personal protective clothing [Smith 1995]. The firefighting drills involved connecting a 5" line to a hydrant, laying hose, and then using an 1 ¾" hose line to move a medicine ball. The FF was the back-up nozzleman during two drills, lasting approximately 8 minutes each with a 15 minute break between the drills during which the participants rehydrated and reloaded hose (SCBA, bunker coat removed). The firefighting drill was performed in full personal protective equipment and SCBA on a warm night, representing heavy physical exertion. Although the night was warm and responders noted the FF's red face following his collapse and attempted to cool him, it is unclear what role heat stress may have played in triggering his sudden cardiac death. The FF did not complain of any symptoms suggestive of heat-illness. Upon arrival at the Emergency Department he was cool to the touch and no measurements of body temperature were obtained.

Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Tofler 1992; Mittleman 1993; Willich 1993;Albert 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, or strenuous physical activity on the job in the preceding 12 hours, increases the risk for a sudden cardiac event [Kales 2003; Hales 2007; Kales 2007]. The FF was involved in training drills that represented heavy physical exertion. The NIOSH investigator concludes that the FF probably died from an arrhythmia associated with a heart attack triggered by the heavy physical exertion associated with the mandatory training drills.

Right Coronary Artery Hypoplasia. In most humans, the right coronary artery branches off the aorta and supplies blood to various portions of the heart muscle. Hypoplasia (small diameter) of the right coronary artery is a rare congenital abnormality that has been associated with an increased risk of cardiac ischemia and sudden cardiac death [Amabile 2005; Wick 2007]. The relative contribution of the FF's hypoplastic right coronary artery to his sudden cardiac death cannot be determined.

Occupational Medical Standards for Structural Firefighting and the Use of the Exercise Stress Test to Screen for CAD. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA has developed NFPA 1582 [NFPA 2007]. NFPA 1582 recommends diagnostic screening for CAD via an exercise stress test for asymptomatic fire fighters over age 45 (55 for women) with two or more risk factors for CAD (family history of premature cardiac event, hypertension, diabetes mellitus, cigarette smoking, and hypercholesterolemia). This recommendation is consistent with recommendations from the American Heart Association/American College of Cardiology [AHA/ACC 2002] and the Department of Transportation [1987] regarding exercise stress tests in asymptomatic persons. Because this FF was only 42 years old and had only one of the CAD risk factors, an exercise stress test would not have been indicated by either NFPA or the American Heart Association/American College of Cardiology. Thus, even if this Fire Department was following NFPA standards, it is unclear if his death could have been prevented at this time.

RECOMMENDATIONS

It is unclear if any of the following recommendations could have prevented the death of this FF at this time. Nonetheless, the NIOSH investigator offers the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters at this, and other, fire departments across the country.

Recommendation #1: Provide mandatory annual medical evaluations to all fire fighters consistent with NFPA 1582 to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

Currently, the Fire Department does not require periodic medical evaluations for fire fighters but does pay for voluntary medical examinations. However, to be consistent with NFPA 1582 and to better ensure the safety of firefighters working at emergency scenes, these examinations should be mandatory. Guidance regarding the content and frequency of periodic medical evaluations and examinations for fire fighters can be found in NFPA 1582 and in the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007]. The Fire Department, however, is not legally required to follow this standard or this initiative.

This recommendation has financial implications and may be particularly difficult for small, volunteer and combination fire departments to implement. The Fire Department may have to consider alternative options to overcome the financial obstacle. One option urges current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and EMTs from the Emergency Medical Service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive 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 Fire Department. Sharing the financial responsibility for these evaluations between fire fighters, the Fire Department, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters. Additional suggestions for overcoming the financial burden of implementing medical examinations within the volunteer service can be found in the National Volunteer Fire Council (NVFC) and United States Fire Administration's (USFA) Health and Wellness Guide for the Volunteer Fire Service [National Volunteer Fire Council 2004].

Recommendation #2: 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.

Physicians who provide input regarding medical clearance for firefighting duties should be knowledgeable about the unique physical demands of firefighting that result from the combination of strenuous physical work, heavy and encapsulating personal protective ensembles, extreme ambient temperatures, and emotional stress. Physicians should also be familiar with a fire fighter's personal protective equipment and the consensus guidelines published by NFPA 1582 [NFPA 2007].

Recommendation #3: Develop a wellness/fitness program for fire fighters to reduce risk factors for CVD and improve cardiovascular capacity.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Physical inactivity, or lack of exercise, is an independent risk factor for CAD and it is positively associated with other risk factors including, obesity, dyslipedemia and diabetes [Plowman and Smith 2003]. NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being [NFPA 2002]. Guidance for how to implement and components of a wellness and fitness program can be found in several documents provided by Fire Service organizations:

- NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters [NFPA 2000];

- International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC), Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007];
- National Volunteer Fire Council (NVFC) / United State Fire Administration (USFA) Health and Wellness Guide for the Volunteer Fire Service [National Volunteer Fire Council 2004].

Implementing a Health and Wellness program is a particular challenge for small, volunteer fire departments. Forming effective partnerships (with park districts, fitness clubs, clinics) and capitalizing on the camaraderie of the fire service may help address these issues.

When considering the cost of Health and Wellness programs it is important to keep in mind the potential cost savings. 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 [Maniscalco 1999; Stein 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey 2002; Womack 2005; Blevins 2006]. A recent 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].

The Fire Department has fitness equipment available and the Volunteer Firefighters Association associated with this department began offering fitness activities for its members shortly after the death of this FF. The program is voluntary and is led by the deputy chief with a background in fitness. The membership has responded enthusiastically and the program currently has a very high participation rate.

Recommendation #4: Provide on-scene rehabilitation to all fire fighters during working fires and training evolutions consistent with NFPA 1584.

Incident scene rehabilitation, as detailed in NFPA 1584, is recommended for emergency scene operations and training where firefighters are required to perform strenuous work for extended periods. Rehabilitation is an intervention designed to mitigate against the physical, physiological and emotional stress of fire fighting in order to sustain a member's energy, improve performance, and decrease the likelihood of on-scene injury or death [NFPA 2008]. Incident scene rehabilitation provides for relief from climatic conditions, rest and recovery, cooling (or heating as warranted), rehydration, calorie and electrolyte replacement, and medical monitoring. During this training exercise fire fighters performed heavy physical exertion in full protective gear on a hot night. Al-

though the instructors provided hydration and rest breaks and it is unlikely heat related illness played a significant role in this FF's death, incident scene rehabilitation should have been established and utilized.

REFERENCES

AHA [2008]. Risk factors and coronary artery disease. [http://americanheart.org/presenter.jhtml?identifier=4726]. Date accessed July 1, 2008.

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 15:296-320.

Amabile N, Fraisse A, Quilici J [2005]. Hypoplastic coronary artery disease; report of one case. Heart 91(2):e12.

Barnard RJ, Duncan HW [1975]. Heart rate and ECG responses of fire fighters. J Occup Med 17(4):247-250.

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.

CDC [2008]. BMI: Body Mass Index. [http://www.cdc.gov/nccdphp/dnpa/bmi]. Accessed August 12, 2008.

CFR [1998]. 29 CFR 1910.134. Occupational Safety and Health Administration: Respiratory Protection. Code of Federal Regulations. Washington, DC: National Archives and Records Administration, Office of the Federal Register.

Davies MJ [1992]. Anatomic features in victims of sudden coronary death. Coronary artery pathology. Circulation 85[Suppl I]:I-19-24.

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.

Farb A, Tang AL, Burke AP, Sessums L, Liang Y, Virmani R [1995]. Sudden coronary death: frequency of active lesions, inactive coronary lesions, and myocardial infarction. Circulation 92:1701-1709.

Hales T, Jackson S, Baldwin T [2007]. NIOSH Alert: Preventing Fire Fighter Fatalities Due to Heart Attacks and Other Sudden Cardiovascular Events. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health Publication No. 2007-133.

IAFF, IAFC [2007]. The fire service joint labor management wellness/fitness initiative. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Jankovic J, Jones W, Burkhart J, Noonan G [1991]. Environmental study of firefighters. Ann Occup Hyg 35(6):581-602.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ Health 2(1):14.

Kales SN, Soteriades ES, Christophi CA, Chirstiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. New 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.

Kung HC, Hoyert DL, Xu J, Murphy SL [2008]. Deaths: Final Data for 2005. National Vital Statistics Reports 56(10).

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

Libby P [2005]. The pathogenesis of atherosclerosis. In: Kasper DL, Braunwald E, Fauci AS, Hauser SL, Longo DL, Jameson JL, eds. Harrison's principles of internal medicine. 16th ed. New York: McGraw-Hill, pp. 1425-1430.

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.

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.

Marius-Nunez AL [1990]. Myocardial infarction with normal coronary arteries after acute exposure to carbon monoxide. Chest 97(2):491-494.

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.

Myerburg, RJ, Castellanos A [2005]. Cardiac arrest and sudden cardiac death. In: Zipes DP, Libby P, Bonow RO, Braunwald E, eds. Braunwald's heart disease: A textbook of cardiovascular medicine. 7th ed. Philadelphia: Elsevier, pp. 865-908.

National Volunteer Fire Council, USFA [2004]. Health and wellness guide for the volunteer fire service, Emmitsburg, MD: Federal Emergency Management Agency: United States Fire Administration, Publication No. FA-267/January 2004.

NFPA [2000]. NFPA 1583: Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association.

NFPA [2002]. NFPA 1500: Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association.

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

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

Plowman SA, Smith DL [2003]. Exercise physiology: for health, fitness and performance. Second edition. San Francisco: Benjamin Cummings.

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

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 42:1148-1155.

Smith DL, Manning TS, Petruzzello SJ [2001]. Effect of strenuous live-fire drills on cardiovascular and psychological responses of recruit firefighters. Ergonomics 44(3):244-254.

Smith DL, Petruzzello SJ, Kramer JM, Warner SE, Bone BG, Misner JE [1995]. Selected physiological and psychobiological responses to physical activity in different configurations of firefighting gear. Ergonomics 38(10):2065-2077.

Thaulow E, Erikssen J, Sandvik L, Erikssen G, Jorgensen L, Cohn PF [1993]. Initial clinical presentation of cardiac disease in asymptomatic men with silent myocardial ischemia and angiographically documented coronary artery disease (The Oslo Ischemia Study). Am J Cardiol 72:629-633.

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 20:1049-1055.

U.S. Department of Labor [2008]. State Occupational Safety and Health Plans. [http://www.osha.gov/dcsp/osp/index.html] Date accessed: August 2008.

Weather Underground [2008]. [http://www.wunderground.com/history/airport/KEFT/2007/6/12/DailyHistory]. Accessed, August 21, 2008.

Wick R, Otto S, Byard RW [2007]. Is right coronary artery hypoplasia and sudden death an underdiagnosed association? Am J Forensic Med Pathol 28(2):128-132.

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 investigation was conducted by and the report written by:

Denise L. Smith, Ph.D.

Dr. Smith is a 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.

Appendix A: Autopsy Findings

Pertinent findings from the autopsy, performed on June 13, 2007 include:

- Cardiomegaly (420 grams; normal being typically <400 grams)
- Atherosclerotic heart disease, severe
  - — Stenosis (narrowing up to 90% blockage)of the left anterior descending artery and branches
  - — Myocardial scar, multifocal
- Congenital hypoplasia (small size) of right coronary artery
- Toxicological analysis noncontributory