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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A summary of a NIOSH fire fighter fatality investigation December 2009

Captain Suffers Sudden Cardiac Death Just After Physical Exercise and One Day After Fire Training – Maryland

SUMMARY

On January 31, 2008 the Captain was an instructor for fireground operations training at the City Training Academy. The following day, February 1, the Captain ran for approximately 1 mile on a treadmill at his home. Shortly after completing the run, he grabbed his chest and collapsed. An ambulance crew from the local volunteer fire department (FD) responded to his residence and initiated advanced life support (ALS). After being worked on for about 30 minutes, the Captain was transported to the local hospital emergency department. ALS measures continued in the emergency department for another 10 minutes without change in the Captain's condition and he was pronounced dead. The medical examiner listed the cause of death as "Hypertensive Atherosclerotic Cardiovascular Disease." NIOSH investigators agree with this assessment and conclude that the physical exertion associated with the Captain's physical fitness program triggered his sudden cardiac death.

NIOSH offers the following recommendations to reduce the risk of heart attacks and sudden cardiac arrest among fire fighters at this and other FD across the country.

- ***Provide mandatory pre-placement and periodic medical evaluations to all fire fighters consistent with the National Fire Protection Association (NFPA) 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.***

INTRODUCTION & METHODS

On February 1, 2008, a 42-year-old career Captain, who also served as a volunteer firefighter in his local community, collapsed and died after running on a treadmill at his home. The Captain had served as an instructor for Fire Rescue training the day before his collapse. NIOSH was notified of this fatality on February 4, 2008 by the U.S. Fire Administration. NIOSH contacted the affected FD shortly thereafter to obtain additional information, and

again on May 21, 2009, to request further information and to schedule the investigation. On June 25 and 26, a contractor for the NIOSH Fire Fighter Fatality Investigation Team (the NIOSH investigator) travelled to Maryland to conduct an on-site investigation of the incident.

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

- Deputy Chief of Training
- Local Union President
- Instructors who worked with the Captain the day prior to his death
- Paramedics and fire fighters who responded to the Captain's residence
- Captain's spouse

The NIOSH investigator reviewed the following documents in preparing this report:

- FD incident report
- Ambulance report
- Death certificate
- Medical examiner's report
- Hospital records
- FD medical records
- Personal physician medical records

INVESTIGATIVE RESULTS

Fire Rescue Training. On January 31, 2008, the Captain served as an instructor for fireground training at the Department's Training Academy. Recruits were involved in training designed to teach basic firefighting skills and practices. The Captain was a support instructor responsible for training evolutions in a six-story training tower. Throughout the day the Captain and one other interior instructor ran recruits through evolutions that involved advancing charged hose lines up five flights of stairs. The Captain oversaw these evolutions for approximately 2 ½ hours in the morning and 2 ½ hours in the afternoon. Supervision of the drills required the instructor to go up-and-down the stairs, typically in full personal protective clothing, to monitor student progress. This type of work would be considered moderate to severe physical exertion.

Instructors who worked with the Captain that day reported that he approached this task in his usual energetic way. He reported no complaints of fatigue, discomfort, chest pain, or unusual shortness of breath.

Fatal Incident. In the early afternoon of February 1st, the Captain engaged in exercise training in the basement of his home. Approximately 6 weeks prior to this incident, the Captain began an exercise program that included 1 mile of treadmill running and occasional short rides on a stationary bike. Crew members reported that he initiated this exercise program to lose weight and improve his physical fitness for an upcoming medical evaluation required for membership on the FD's Hazardous Materials (HAZMAT) team.

The Captain's wife reported that after running 1 mile (in approximately 12-13 minutes) he

cooled down and got off the treadmill. While walking behind a sofa and toward the exercise bike he grabbed his chest, fell into the sofa, and then fell backward onto the basement floor. His wife immediately went upstairs and dialed 911. The call was received at 1340 hours and an ambulance with the local volunteer FD was dispatched at 1344 hours. A support vehicle with additional Emergency Medical Service (EMS) personnel was also dispatched shortly thereafter.

When the ambulance and EMS personnel arrived on-scene at 1346 hours, they found personnel from the County Sheriff's office performing cardiopulmonary resuscitation (CPR). Initial assessment found the Captain to be cyanotic with dilated and non-reacting pupils. EMS personnel attached the Captain to a cardiac monitor showing a heart rhythm of ventricular fibrillation (VFIB). A shock (defibrillation) of 360 joules was administered, but the Captain's heart rhythm went into asystole (no heartbeat). The Captain was intubated with tube placement confirmed by an end tidal carbon dioxide detection devise. An intravenous line was placed and followed by the administration of epinephrine and atropine.

The Captain's heart rhythm fluctuated between VFIB and asystole during ALS resuscitation efforts. CPR continued and the Captain was secured onto a stretcher for transport. The ambulance arrived at the hospital's emergency department at 1420 hours. At this point it had been 40 minutes since the Captain's collapse. The Captain's heart was in VFIB on arrival in the emergency department. ALS protocols were continued for an additional 10 minutes without a change in his clinical condition. At 1425 his heart went into asystole for the final time. At 1430 hours he was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. The autopsy, completed by an Assistant Medical Examiner on February 2, 2008, listed "Hypertensive Atherosclerotic Heart Disease" as the cause of death. The autopsy found significant atherosclerosis with blockages in all three of his coronary arteries. (See Appendix A for pertinent autopsy findings.) The Captain had several risk factors for coronary heart disease. He had a history of high blood cholesterol for which he was started on prescription medication in 2000. He had high blood pressure (hypertension) for which be began medical treatment in 2006. Hhe had a significant family history of cardiovascular disease.

In December 2005, the Captain had a medical evaluation as part of is FD's HAZMAT program. This evaluation revealed a body mass index (BMI) of 32 placing him in the obese category according to CDC guidelines [CDC 2009]. The Captain was instructed to lose weight by proper diet and exercise. He was medically cleared for the position.

The local firefighter's union offers a physical fitness assessment program (free of charge) and a heart/lung scan for a nominal fee. The Captain participated in this program at the end of 2005. The heart scan revealed an elevated calcium score (559.9) indicating significant calcified plaque in the coronary arteries. Specifically, the scan revealed significant calcifi-

cation distributed primarily in the left anterior descending coronary artery. Based on the results of the heart scan, the Captain followed up with his primary care physician and was scheduled for a cardiology consultation.

During the cardiology consultation in the spring of 2006, the Captain reported a lack of regular exercise and becoming short of breath when climbing six flights of stairs while working as a fire officer. He denied chest pain, dizziness, syncope, or palpitations during such exertion. At this time the Captain was taking medication for high blood cholesterol and a low dose aspirin (81 milligrams) daily. The cardiologist ordered a thallium exercise stress test and an echocardiogram, and initiated medical treatment for hypertension.

On the exercise stress test, the Captain exercised for 12:45 minutes reaching stage V of the Bruce protocol [12.8 metabolic equivalents (METS)]. The test was discontinued because of fatigue and shortness of breath. The Captain experienced no chest pain during the test and had no heart arrhythmias. His blood pressure response was on the high end of normal (190/98 mmHg). The electrocardiogram (EKG) showed no ischemic changes. The imaging (thallium) portion of the test indicated no transient or fixed perfusion abnormalities and no wall motion abnormalities with a left ventricular ejection fraction of 62% (normal). The echocardiogram revealed "normal" left ventricular size and function (ejection fraction of 60-65%) although it did note mild concentric left ventricular hypertrophy and mild left atrial enlargement (4.3 cm).

As mentioned earlier, the Captain had recently initiated (approximately 6 weeks prior to his death) an exercise program that included treadmill running and stationary cycling. It was also reported that he was conscious of his diet and was motivated to lose weight.

DESCRIPTION OF THE FD

The FD consists of approximately 1800 uniformed personnel serving in 40 fire stations. The FD serves a population of over 600,000 in an area of approximately 80 square miles. The FD responded to approximately 235,000 calls in 2008.

Employment and Training. The FD requires applicants to complete an application form and take a general aptitude test. Individuals who pass the written test complete a physical ability test. A background test is conducted before an offer of employment is made. A candidate is provisionally offered a position contingent upon passing a medical evaluation (described below). Upon hiring, a probationary firefighter spends 6 months at the Training Academy to become certified as a Firefighter II, a emergency medical technician, and HAZMAT at the operational level.

The Captain was hired in 1993 and advanced through the rank of emergency vehicle operator and lieutenant, becoming a Captain in 2006. He was a certified Emergency Medical Technician – Intermediate and was a Hazardous Materials Technician. The Captain regularly served as an adjunct instructor at the Fire Academy.

Pre-placement Medical Evaluations. A pre-placement medical evaluation is required of all new recruits. The pre-placement medical evaluations are performed by a physician's group under contract to the City. The medical evaluation includes a medical history, blood pressure measurement, physical examination, blood work for complete blood cell count and cholesterol, urinalysis, drug screen, spirometry, resting EKG, hearing test (audiometry), and vision test (Snellen).

Periodic Medical Evaluations. Periodic medical evaluations are not required by the FD, but HAZMAT members must undergo periodic medical evaluations.

Fitness/Wellness Programs. The FD does not offer a health and wellness program but most fire stations have some aerobic exercise equipment and weight machines. Members are allowed to exercise while on duty. As mentioned earlier, the local Union offers a physical assessment program (free of charge) along with an opportunity to obtain a heart scan (calcium scan) for a nominal fee.

DISCUSSION

CAD and the Pathophysiology of Sudden Cardiac Death. This Captain suffered sudden cardiac death after working out on a treadmill. 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 2009]. This Captain had CAD as confirmed at autopsy. 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 a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. The Captain did not have a heartbeat on which to conduct an EKG, cardiac enzymes were not tested, and no thrombus was identified at autopsy. Occasionally (16%–27% of the time), postmortem examinations do not reveal the coronary artery thrombus/plaque rupture during acute heart attacks [Davies 1992; Farb et al. 1995]. Based on the clinical scenario with autopsy findings showing significant atherosclerotic coronary disease, the Captain probably suffered a heart attack. However, a primary heart arrhythmia cannot be ruled out.

The Captain collapsed shortly after completing a short workout on a treadmill. The exercise he performed was typical of the exercise he had been doing for approximately 6 weeks as part of his individualized physical fitness program. His wife reported that his time to complete the mile (approximately 12-13 minutes) was one of his best times. This most likely represented a strenuous workload for the Captain.

Epidemiologic studies in the general population have found that heavy physical exertion

can trigger a heart attack and cause sudden cardiac death [Tofler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 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 et al. 2003; Hales et al. 2007; Kales et al. 2007]. The Captain taught basic firefighting skills to recruits for several hours on the day before his collapse. It is thought that the Captain was wearing full PPE and that as part of his duties he would have climbed and descended the stairs many times throughout the day. This activity would be categorized as moderate exertion. It is unclear if this activity could have triggered his cardiac event approximate 24 hours later. Based on the findings discussed above, the NIOSH investigator concluded that the Captain died from a probable heart attack.

Primary Arrhythmia. Because of the lack of definitive evidence of a heart attack it is possible that the Captain's sudden cardiac death was caused by a primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation). Risk factors for arrhythmias include heart disease, heart attack, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [AHA 2009]. The Captain's underlying heart disease of CAD and mild LVH were his only risk factors for a primary arrhythmia.

Occupational Medical Standards for Structural Firefighting. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA has developed NFPA 1582 [NFPA 2007a]. NFPA 1582 recommends that all firefighters receive annual medical evaluations. NFPA 1582 also 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 similar to recommendations from the AHA/ACC and the Department of Transportation regarding exercise stress tests in asymptomatic persons [Gibbons et al. 2002; Blumenthal et al. 2007].

The Captain was only 42 years old so an exercise stress test was not required for asymptomatic people based on NFPA or AHA/ACC guidelines. However, due to his coronary artery calcium score (discussed below), his report of chest discomfort, and his fire fighter profession, the Captain did have an imaging stress test. The tests results indicated normal EKG, normal perfusion, and normal function. The negative thallium stress test indicates that the plaque did not completely occlude the arteries and the Captain was able to perform exercise without evidence of perfusion abnormalities or ischemia. These findings are consistent with a clinical scenario of a heart attack caused by plaque rupture with the formation of a blood clot that acutely occludes the coronary artery.

Coronary Artery Calcium Scan. The Captain had received a coronary artery calcium scan offered through the local Union. The coronary calcium score is a screening test to help assess

the risk of coronary artery disease. The scan quantifies the calcified atherosclerotic plaque in the coronary arteries and provides a score that describes its severity. Although coronary artery calcification is always present in persons with coronary artery disease, it does not correlate highly with the extent of stenosis [Budoff et al. 2006]. The Captain had a calcium score of 559.9 which indicates significant calcification and suggests that the Captain was at increased risk for a sudden cardiac event.

In this case the coronary artery calcium score was a better predictor of a future cardiac event that the imaging stress test. The medical community continues to assess the best way to screen asymptomatic individuals for coronary artery disease [Gibbons et al. 2002; U.S. Preventative Services Task Force 2004; Greenland et al. 2007].

RECOMMENDATIONS

NIOSH offers the following recommendations to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters at FDs 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.

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* [IAFF/IAFC 2007; NFPA 2007a].

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.

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 2007]. According to these guidelines, the FD 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 2007]. The physician should review job descriptions and essential job tasks required for all FD positions and ranks 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 #3: Develop a comprehensive wellness/fitness program for fire fighters

to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.

Guidance for FD wellness/fitness programs is found in NFPA 1583, S*tandard 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 2007; USFA 2004; NFPA 2008]. 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; Elliott et al. 2007]. A study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large FDs implementing the IAFF/IAFC wellness/fitness program compared to four large FDs 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].

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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 Health and Exercise Sciences, 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 Heath, and Vice Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A

Pertinent Autopsy Findings

- Coronary Arteries
  - — 80% calcified atherosclerotic stenosis of the left main coronary artery,
  - — 70% calcified atherosclerotic stenosis of the proximal left anterior descending coronary artery,
  - — 95% stenosis of the right coronary artery.
- Microscopic analysis revealed myocyte hypertrophy and fibro-calcified atheromatous plaque of the coronary arteries.
- Blood tests were negative for alcohol and other elicit drugs.