2012
18

Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *August, 2012*

Fire Marshal Suffers Cardiac Arrest and a Probable Heart Attack during a Fire Department Physical Ability Test – Utah

Executive Summary

On August 26, 2011, a 55-year-old male Fire Marshal suffered a sudden cardiac event during a fire department (FD) physical ability test (PAT). The test, a job-related simulation, involved completing 10 evolutions of essential fire fighter tasks in full turnout gear and self-contained breathing apparatus (off-air / no mask) within 19 minutes. The test began about 0715 hours at the FD headquarters with two test proctors and two FD members from the adjoining fire station in attendance. The Fire Marshal completed the first 8 evolutions without any difficulty. About halfway along the ninth evolution the Fire Marshal stumbled and fell while dragging a 175-pound manikin. After taking a short break to catch his breath, he said "I gotta finish," and proceeded to the apparatus bay for the last evolution. The Fire Marshal looked exhausted; he was very short of breath and had ashen skin color and cyanotic lips. He was unable to complete the evolution before the 19-minute PAT completion time elapsed.

He flopped into a chair and then asked to lie down. His breathing became very shallow and fast as his turnout coat was removed. He was treated at the scene for low oxygen saturation and low blood pressure. As the Fire Marshal was loaded into the ambulance he suffered a cardiac arrest, but regained a heart rhythm enroute to the local hospitals emergency department (ED). Upon arrival at the ED, the Fire Marshal was hypotensive and unresponsive. Subsequent blood tests indicated a probable heart attack. The Fire Marshal did not regain consciousness and died on August 28, 2011.

The death certificate and the autopsy, both completed by the assistant medical examiner, listed "hypertensive cardiovascular disease" as the cause of death. Given the Fire Marshal's cardiac findings at autopsy (concentric left ventricular hypertrophy (LVH) and focal acute myocardial infarction [heart attack] of the posterior wall), the NIOSH investigator concludes that the heavy physical exertion required to complete the PAT in full turnout gear triggered a heart attack and/or a heart arrhythmia (asystole) which resulted in cardiogenic shock.

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

- Strengthen the FD's Annual Medical Assessment Program to be consistent with the National Fire Protection Association (NFPA) 1582 by:
  - Ensuring that fire fighters are medically cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.
  - Including a comprehensive medical and work history form in the medical assessment.
  - Ensuring that the annual 12-lead resting electrocardiogram (EKG) conducted by the FD paramedics is reviewed by the FD physician and included in the member's FD medical file.

Fire Marshall Suffers Cardiac Arrest and a Probable Heart Attack during a Fire Department Physical Ability Test – Utah

Fire Marshall Suffers Cardiac Arrest and a Probable Heart Attack during a Fire Department Physical Ability Test – Utah

Executive Summary (cont.)

  - Conducting symptom-limiting exercise stress tests for fire fighters at risk of coronary heart disease (CHD).
  - Eliminating annual chest x-ray for members, unless clinically indicated.
  - Including an annual urinalysis or a urine dipstick test.
- Consider modifying the physical fitness policy by:
  - Developing a separate physical ability policy.
  - Removing the employment consequences for members who fail to achieve the established benchmarks.
- Avoid back-to-back work shifts.

Introduction & Methods

On August 26, 2011, a 55 year-old Fire Marshal collapsed during the FD's PAT. Fellow fire fighters initiated immediate medical care, which was followed by treatment at the local and tertiary hospitals. Despite these efforts, the Fire Marshal died on August 28, 2011. NIOSH was notified of this fatality on August 30, 2011, by the U.S. Fire Administration. NIOSH contacted the affected FD on September 2, 2011, to obtain additional information and again on May 30, 2012, to schedule the investigation. On July 9, 2012, the physician with 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
- Two Deputy Fire Chiefs
- FD members present during the PAT
- FD paramedics who treated the Fire Marshal

Introduction & Methods (cont.)

- Fire Marshal's wife
- Fire Marshal's son
- Consultant who developed the FD's physical fitness policy and PAT
- Assistant Medical Examiner who performed the autopsy

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

- FD incident report
- FD witness statements
- FD job descriptions
- FD standard operating procedures – physical fitness policy
- FD ambulance care report
- FD medical records
- Death certificate
- Medical examiner's report of examination (autopsy)
- Hospital records
- Personal physician medical records

Investigative Results

Background. In 2008, the FD initiated a physical fitness policy. This policy was developed and validated in collaboration with a local expert in public safety fitness. It included job-related simulation tests. The primary goal of the policy was to ensure the safe and effective performance of the essential job functions of all sworn fire fighters.

The policy was implemented in two-phases. Phase 1, in effect from 2008 to 2010, required fire fighter participation in all components of the fitness program, but did not have employment consequences for fire fighters not passing the physical fitness test (PFT). Phase 2, in effect since the fall of 2011, required not only participating in the fit-

Fire Marshall Suffers Cardiac Arrest and a Probable Heart Attack during a Fire Department Physical Ability Test – Utah

Investigative Results (cont.)

ness program, but passing the PFT (Appendix A) or the PAT (Appendix B) annually.

The fitness program was overseen by the FD's Wellness Coordinator, Health Safety Officer, and Peer Fitness Coordinator. It included five components:

1) Annual medical and health screening (discussed later in this report)
2) Semi-annual PFT (Appendix A) or annual PAT (Appendix B)
3) Physical fitness and health education
4) Individualized exercise prescription
5) Opportunity to self-assess each portion of the PFT

The Fire Marshal took advantage of the individualized training offered by the FD. He took the PFT twice a year beginning in 2009. He passed all components except the run, in part due to an Achilles tendon injury in 2011 that precluded training. As a result of not passing the run portion of the PFT on August 13, 2011, he was scheduled for the PAT on August 26, 2011.

Incident. On August 26, 2011, the Fire Marshal arrived at FD headquarters with his personal trainer a little before 0700 hours to complete the PAT. The test, a job-related simulation, involved completing 10 evolutions of essential fire fighter tasks within 19 minutes (Appendix B). The Fire Marshal did a walk-through of the PAT with the two FD test proctors who discussed the order of the 10 evolutions. He then put on his turnout coat, pants, wildland hard hat, leather gloves, and Redback® boots, and donned his self-contained breathing apparatus (with no mask and off-air). He began the PAT at 0715 hours. Two FD members from the adjoining fire station were in attendance. Air temperature was between 77–80 degrees Fahrenheit (dry bulb) with 37–40% relative humidity with a wind speed of between 14–20 miles per hour [NOAA 2011].

The Fire Marshal completed the first six evolutions without difficulty. During the seventh (hose drag) and eighth (tool crawl) evolutions, he stumbled once, but seemed fine and reported that he was okay. About halfway along the ninth evolution (victim rescue), the Fire Marshal stumbled and fell. He fell three times while dragging the 175-pound manikin the last 50 feet of the evolution. At the end of the evolution his legs become tangled with the manikin's legs and he had difficulty standing up. He took a 60-second break in the parking lot to catch his breath. Test proctors and the other two FD members noted that he was very short of breath. When they gave words of encouragement, the Fire Marshal said "I gotta finish," and he proceeded to the apparatus bay for the last evolution.

The last evolution was the ceiling breech and pull with a pike pole. By this time, the Fire Marshal looked exhausted. He was very short of breath, and had ashen skin color with cyanotic lips. He completed about half of the evolution when the 19-minute PAT completion time elapsed. When he realized he did not pass the test, he flopped into a chair and then asked to lie down.

The Fire Marshal's turnout coat was removed and water was splashed on his head; his breathing became shallow and very fast. A pulse oximeter showed a 70% saturation and his blood pressure was low (70/30 mmHg). He was given oxygen via a non-rebreather mask and a nebulized albuterol® treatment as the FD paramedics at a

Investigative Results (cont.)

neighboring station were radioed to respond to FD headquarters.

The Fire Marshal was loaded into the ambulance by crewmembers as the paramedics arrived at 0748 hours. The paramedics started an intravenous (IV) line, attached a cardiac monitor, provided oxygen by bag-valve mask, and departed for the local hospital's ED. Enroute, the Fire Marshal's heart rate slowed and then stopped (asystole). Atropine was administered and his heart rate returned (40 beats per minute), but he remained hypotensive (blood pressure 60/41 mmHg) and unresponsive. Just prior to arrival in the ED (0752 hours), an external pacemaker was successfully inserted with capture.

Upon admission to the ED the Fire Marshal remained hypotensive and unresponsive. An EKG showed sinus tachycardia, but no obvious signs of a cardiac injury or ischemia. His initial blood test to diagnose a heart attack was negative (troponin I was <0.02 ng/dL), but the afternoon and evening troponin I tests were significantly elevated (>25 ng/dL and 93 ng/dL, respectively) indicating significant cardiac damage. An echocardiogram done in the intensive care unit showed normal biventricular size, low-normal function (left ventricular ejection fraction 55%), no valvular abnormalities, and no pericardial effusion. This was very surprising (ejection fraction of 55%) given the Fire Marshal's profound hypotension. Despite aggressive care, the Fire Marshal remained in cardiogenic shock and did not regain consciousness. Due to his grave prognosis, he was transferred by helicopter to a tertiary care hospital for further evaluation and treatment. Despite intensive care at the tertiary hospital for approximately 30 hours, the Fire Marshal died on August 28 at 1432 hours.

Medical Findings. The death certificate, completed by the Assistant Medical Examiner for the State Department of Health, listed the immediate cause of death as "hypertensive cardiovascular disease." The autopsy, also done by the Assistant Medical Examiner, revealed concentric left ventricular hypertrophy, no significant atherosclerosis or thrombosis in the coronary arteries, "hemorrhage in the posterior papillary muscle suggestive of acute ischemia/infarction", and microscopic "section of the posterior left ventricle reveals acute myocardial infarction with hemorrhage and neutrophilic infiltration." See Appendix C for a more complete listing of pertinent autopsy findings.

The Fire Marshal had a history of hypertension diagnosed in 1999 with complications of nephrosclerosis with chronic renal insufficiency [baseline creatinine of 1.6 milligrams per deciliter (mg/dL) and baseline blood urea nitrogen of 26 mg/dL]. This complication occurred despite his blood pressure being fairly well controlled on medications since 1999. His last blood pressure measured 6 weeks prior to his death was 128/86 mmHg in his left arm and 132/90 mmHg in his right arm.

The Fire Marshal was diagnosed with hyperlipidemia in 2005. This condition was well controlled with diet, weight loss, and prescription medications. His last blood tests were done 6 weeks prior to his death; results included triglycerides of 164 mg/dL (normal <150 mg/dL), total cholesterol of 147 mg/dL (normal < 200 mg/dL), LDL cholesterol of 74 mg/dL (normal <130 md/dL), and HDL cholesterol of 41 mg/dL (normal 40-60 mg/dL).

In 2009 the Fire Marshal was diagnosed with gastroesophageal reflux disorder (GERD) which was successfully treated with Prilosec®. The Fire

Fire Marshall Suffers Cardiac Arrest and a Probable Heart Attack during a Fire Department Physical Ability Test – Utah

Investigative Results (cont.)

Marshal also had been treated for exercise-induced asthma since 2010 with an inhaler, but had always had normal pulmonary function tests. Primary care provider records reported the Fire Marshal experienced some dyspnea on exertion, but no orthopnea, paroxysmal nocturnal dyspnea, pedal edema, chest pain, or palpations. The Fire Marshal was 72 inches tall and weighed approximately 245 pounds (body mass index of 33.2 kilograms per meter squared) [CDC 2011]. The Fire Marshal exercised regularly since 2009, including during the months leading up to his PFT. He took advantage of the peer fitness coordinators to develop an individualized exercise plan in 2009 and 2010. More recently, he was working with a personal trainer at his expense.

Description of the Fire Department

The FD has 94 sworn members (56 full-time and 38 part-time) operating from five fire houses. The FD covers 40 square miles and serves a population of 95,000. In 2011, the FD responded to over 5,600 calls.

Candidates. FD candidates must be a State certified fire fighter I and at least an EMT-I. Candidates who submit their applications are required to pass the PFT and the PAT. The applicant must then take a written medical and fire service test administered by a third party followed by a medical skills test and a fire skills test. The candidates are then ranked, and interviewed by the Fire Chief. Once hired, they are on probation for 1 year. The Fire Marshal was hired as a part-time fire fighter in 1989, and converted to full-time in 1994. In 2000 he was promoted to Fire Marshal. He had over 22 years of fire fighting experience.

Description of the FD (cont.)

Medical Evaluations for Candidates and Members. Candidates: Prior to 2005, the FD required a pre-placement medical evaluation for all candidates. However, the components of these medical evaluations were not specified, and the evaluation could be completed by the candidate's personal physician.

Members: In 2008, as part of the FD's physical fitness policy, the FD required an annual medical assessment. This assessment could be performed by the FD contract physician or the member's personal health care provider (physician, nurse practitioner, or physician assistant). The health care provider was responsible for the physical examination, while the laboratory testing was done at the local hospital. The laboratory work included:

- Blood tests (complete blood count, chemistries, lipid profile, and prostate specific antigen for male members over the age of 40)
- Pulmonary function tests
- Chest X-ray
- Vision test
- Audiogram (every other year)
- Tuberculosis skin test (every 4 years)
- Resting EKG conducted by the FD paramedics

Respiratory fit testing and medical clearance to wear a self-contained breathing apparatus is required and provided by the FD annually. The Fire Marshal had an annual medical assessment in 2009, 2010, and 2011 by his primary care provider. At this time, the FD did not require a provider statement regarding medical clearance to participate in the PFT, the PAT, or unrestricted fire fighting duties.

Discussion

Pathophysiology of Sudden Cardiac Events. Based on autopsy findings (hemorrhage and neutrophilic infiltration of the posterior wall of the heart) and cardiac enzymes at the hospital, the Fire Marshal most likely had a heart attack during a physically demanding PAT and subsequently suffered a cardiac arrest (asystole). The most common risk factor for cardiac arrest and sudden cardiac death is CHD. CHD is defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2012]. Although the FF had a history of treated hypertension and hyperlipidemia, he was not known to have CHD prior to his death nor was significant CHD found at autopsy. Therefore, the Fire Marshal's heart attack may have been caused by prolonged coronary artery spasm [Stern and de Luna 2009].

Establishing the occurrence of a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. No thrombus was identified at autopsy. However, 16%–27% of postmortem examinations do not reveal the coronary artery thrombus/plaque rupture during acute heart attacks [Davies 1992; Farb et al. 1995]. The FF had an EKG that did not show findings consistent with an acute myocardial infarction, however, posterior wall myocardial infarctions are known to be difficult to diagnose by EKG [van Gorselen et al. 2007]. The cardiac enzymes (troponin 1) were initially negative, but become markedly positive during the afternoon and evening. This pattern is consistent with a heart attack.

Symptoms of angina (chest pain due the heart muscle not getting enough oxygenated blood through the coronary arteries) are one of the best indicators of CHD and/or heart attacks. Although the Fire Marshal did not express any chest pain, he was diagnosed with heartburn (GERD) 2 years before his death. Up to 20% of patients have asymptomatic or atypical angina such as heartburn [Libby 2005; Selwyn and Braunwald 2005]. Given that the Fire Marshal's symptoms of GERD improved with Prilosec®, most likely he had asymptomatic angina. His marked shortness of breath was probably related to the heart failure associated with his heart attack.

Although the Fire Marshal suffered a cardiac arrest, this condition was quickly treated by the FD paramedics and his heart rhythm was not a significant factor in his deteriorating condition. Therefore, based on the autopsy findings and the cardiac enzymes, the Fire Marshal's death was most likely caused by a heart attack and subsequent cardiogenic shock.

Physiological Stress of Firefighting. Firefighting is widely acknowledged to be physically demanding. Firefighting activities require fire fighters to work at near maximal heart rates for long periods. An increase in heart rate typically occurs in response to the initial alarm and persists throughout the course of fire suppression activities [Barnard and Duncan 1975; Lemon and Hermiston 1977; Manning and Griggs 1983; Smith et al. 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 et al. 1995].

Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death

Discussion (cont.)

[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 Fire Marshal was involved in heavy physical exertion associated with the PAT. This exertion probably triggered his cardiac arrest and/or his heart attack.

Left Ventricular Hypertrophy (LVH). The autopsy revealed that the Fire Marshal had concentric LVH. This condition increases the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the left ventricle is relatively common among individuals with long-term hypertension, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The Fire Marshal had a long history of high blood pressure. Although it had been fairly well-controlled with medications since 1999, high blood pressure was the most likely cause of his LVH. It is unclear why this finding was not diagnosed with during the echocardiogram performed in the intensive care unit. Similarly, it is unclear why the echocardiogram showed low-normal left ventricular ejection fraction (55%) while the Fire Marshal was in cardiogenic shock.

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 an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for "informational purposes only." Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter's aerobic capacity. Maximal (e.g., symptom-limiting) stress tests with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease
- two or more risk factors for CHD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter), hypertension (diastolic blood pressure greater than 90 mm of mercury), smoking, diabetes mellitus, or family history of premature CHD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

It is important to note that several organizations have published guidelines on exercise stress tests for asymptomatic individuals that differ from the NFPA. One organization is the American College of Cardiology/American Heart Association (ACC/AHA) [Gibbons et al. 2002]. The ACC/AHA guideline states exercise testing in asymptomatic people could be considered for the following groups based on "Class IIb" evidence ("less well established"):

- persons with multiple risk factors (defined similarly to those listed by the NFPA)
- asymptomatic men older than 45 years and women older than 55 years:
  - who are sedentary and plan to start vigorous exercise
  - who are involved in occupations in which

Discussion (cont.)

impairment might jeopardize public safety (e.g., fire fighters)
- who are at high risk for coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation provides guidance for those seeking medical certification for a commercial drivers' license. An expert medical panel recommended exercise tolerance tests (stress tests) for asymptomatic "high risk" drivers [Blumenthal et al. 2007]. The panel defines high risk drivers as those with any of the following:

- diabetes mellitus
- peripheral vascular disease
- age 45 and above with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, the USPSTF found "insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning…." Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004]. The USPSTF does note that "For people in certain occupations, such as pilots and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease."

The Fire Marshal had several risk factors for CHD (treated hypertension, treated hyperlipidemia, and chronic renal insufficiency). Therefore a stress test was indicated based on the 2007 edition of NFPA 1582, the ACC/AHA, and the U.S. Department of Transportation.

Recommendations

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

Recommendation #1: Strengthen the FD's Annual Medical Assessment Program to be consistent with the National Fire Protection Association (NFPA) 1582 by:

1a) Ensuring that fire fighters are medically cleared for duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582. Prior to 2012, the FD allowed members the option of seeing their personal health care provider for medical clearance. These health care providers may be unaware of the physiological and psychological demands of structural fire fighting. Beginning in January 2012, the FD required that the medical assessment be conducted a FD or FD-contracted physician. Once the FD physician has completed the medical assessment, a medical release form should be signed by the physician or health care provider stating that they have reviewed the physiologic requirements of the position and have medically cleared the fire fighter for duty. The Fire Marshal's last FD medical assessment, conducted 6 weeks prior to his death, did not identify any medical conditions requiring restrictions or precluding participation in the PAT.

Recommendations (cont.)

1b) Including a comprehensive medical and work history form in the medical assessment. An example of a comprehensive form for fire fighters is one developed by the U.S. Department of Interior [DOI 2011].

1c) Ensuring that the annual 12-lead resting EKG done by the FD paramedics is reviewed by the FD physician and included in the member's FD medical file.

1d) Conducting symptom-limiting exercise stress tests for fire fighters at risk of CHD. As mentioned in the discussion section, conducting exercise stress tests on asymptomatic patients is controversial. However, given the Fire Marshal's CHD risk profile, several organizations (NFPA, the ACC/AHA, and the US Department of Transportation) would have recommended the test. It is unclear if an exercise stress test would have identified the Fire Marshal's underlying heart condition.

1e) Eliminating annual chest x-ray for members, unless clinically indicated. Chest x-rays are done every year as part of the FD's annual medical assessment. According to NFPA 1582, "chest x-rays shall include an initial baseline and shall be repeated every 5 years or as medically indicated" [NFPA 2007a]. Doing chest x-rays every year, or even every 5 years, exposes members to unnecessary radiation and represents an unnecessary expense for the FD. Routine screening chest x-rays are not recommended by the OSHA Hazmat Standard, unless clinically indicated (e.g., respiratory symptoms) [NIOSH 1985; CFR 2012].

1f) Including an annual urinalysis or a urine dipstick test

Recommendation #2: Consider modifying the physical fitness policy by:

2a) Developing a separate physical ability policy. We applaud the FD for undertaking the significant effort of developing, validating, and implementing an annual PAT as required by NFPA 1500 [NFPA 2007b]. The physical ability policy and the PAT should be reviewed at least annually with the FD expert consultant. If changes are made to the policy or the test, these changes (with justification for the change) should be communicated to the entire sworn staff. Members and candidates should be provided the opportunity to practice the PAT on a regular basis (e.g., quarterly or bimonthly). A FD safety officer should provide oversight during the test/practice sessions and consider monitoring the participant's vital signs before and after the session. Any candidate or member requiring medical treatment (e.g., IV fluids) or transport should be reported to, and tracked by, the FD administration.

2b) Removing the employment consequences for members who fail to achieve the established benchmarks. Again, we applaud the FD for undertaking the significant effort of developing, validating, and implementing an annual PFT as required by NFPA 1583 [NFPA 2008]. The FD's physical fitness program has all the major components required by NFPA 1583. However, the purpose of NFPA 1583 is to enhance the member's ability to perform their essential job duties efficiently and safely. It was not intended to establish physical performance criteria. "A.1.2.2 The intent of this program is to promote health and fitness in a 'mandatory, nonpunitive' manner. 'Mandatory, nonpunitive' implies a program with universal participation; however failure to achieve defined or individual fitness objectives should not

Recommendations (cont.)

be the basis for any employment sanctions, discipline, or other punitive actions" [NFPA 2008]. The FD provided a 3- year phase-in period (2008-2010) and allows multiple attempts to pass the test. However, if the FD member cannot pass the PFT, employment may be affected.

The physical fitness policy and the PFT should be reviewed at least annually with the FD expert consultant. If changes are made to the policy or the test, these changes (with justification for the change) should be communicated to the entire sworn staff. Any candidate or member requiring medical treatment or transport during training or during the PFT should be reported to, and tracked by, the FD administration.

Recommendation #3: Avoid back-to-back work shifts.

In 2004, NIOSH reviewed the research literature on the health effects of overtime and extended work shifts (typically 12-hour shifts compared to 8-hour shifts). Overtime was associated with poorer perceived general health, increased injury rates, more illnesses, or increased mortality in 16 of 22 studies reviewed [NIOSH 2004]. Extended work shifts were associated with decreased alertness, increased fatigue, lower cognitive function, declines in vigilance, and increased injuries [NIOSH 2004]. Studies among physicians who worked very long shifts (>24 hours) reported deteriorating cognitive performance, more frequent patient errors, and more frequent motor vehicle accidents after their shift [NIOSH 2004; Barger et al. 2005; Barger et al. 2006].

FD personnel work 48 hours followed by 96 hours off. Fire fighters are allowed to exchange shifts, thereby setting up the possibility that a fire fighter may be on duty for up to 96 hours. While District fire fighters frequently get some sleep during their work shifts, this sleep can be interrupted by numerous ambulance calls made during the night and early morning hours. Although there are no data linking chronic sleep deprivation with sudden cardiac death, chronic sleep deprivation could result in a decline in cognitive function, possibly impairing judgment during incident command or fire suppression. Allowing fire fighters to work back-to-back consecutive shifts may represent not only an injury and illness risk for individual fire fighters, but may also represent a safety and health risk for their coworkers and the public.

References

AHA (American Heart Association) [2012]. Understand Your Risk of Heart Attack. [http://www.heart.org/HEARTORG/Conditions/HeartAttack/UnderstandYourRiskofHeartAttack/Understand-Your-Risk-of-Heart-Attack_UCM_002040_Article.jsp]. Date accessed: July 26, 2012.

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.

Barger L, Ayas N, Cade B, Cronin J, Rosner B, Speizer F, Czeisler C [2006]. Impact of extended-duration shifts on medical errors, adverse events, and attentional failures. PLoS Med 3:e487. [http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0030487&ct=1]. Accessed on: July 26, 2012.

References (cont.)

Barger L, Cade B, Ayas , Cronin J, Rosner B, Speizer F, Czeisler C; Harvard Work Hours, Health, and Safety Group [2005]. Extended work shifts and the risk of motor vehicle crashes among interns. N Engl J Med 352(2):125-34.

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

Blumenthal RS, Epstein AE, Kerber RE [2007]. Expert Panel Recommendations. Cardiovascular disease and commercial motor vehicle driver safety. [http://www.mrb.fmcsa.dot.gov/documents/CVD_Commentary.pdf]. Date accessed: July 26, 2012.

CDC (Centers for Disease Control and Prevention) [2011]. Body Mass Index. [http://www.cdc.gov/healthyweight/assessing/bmi/]. Date accessed: July 26, 2012.

CFR [2012]. Code of Federal regulations [29 CFR 1910.120]. OSHA Standards Interpretation. Medical Surveillance Requirements for Hazmat Workers. Washington, DC: U.S. Government Printing Office, Office of the Federal Register. [http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=28301]. Date accessed: July 26, 2012.

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

DOI [2011]. Department of the Interior Wildland Firefighter Medical Standards Program (DOI MSP) Annual Exam Packet. [http://www.nifc.gov/medical_standards/documents/NewExamProcess/Annual_Exam_Packet.pdf]. Date accessed: July 28, 2012.

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(7):1701–1709.

Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr. [2002]. ACC/AHA 2002 guideline update for exercise testing: summary article: a report of the ACC/AHA Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). J Am Coll Cardiol 40(8):1531– 40.

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. [http://www.cdc.gov/niosh/docs/2007-133/]. Date Accessed: December 17, 2010.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Fire fighters 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.

Lemon PWR, Hermiston RT [1977]. The human energy cost of fire fighting. J Occup Med 19(8):558-565.

References (cont.)

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 [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, NY: McGraw-Hill, pp. 1425-1430.

Manning JE, Griggs TR [1983]. Heart rates in fire fighters using light and heavy breathing equipment: Similar near-maximal exertion in response to multiple work load conditions. J Occup Med. 25(3): 215-218.

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.

Mittleman MA, Maclure M, Sherwood JB, Mulry RP, Tofler GH, Jacobs SC et al. [1995]. Triggering of acute myocardial infarction onset by episodes of anger. Determinants of Myocardial Infarction Onset Study Investigators. Circulation 92(7):1720-1725.

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

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

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

NIOSH [2004]. Overtime and Extended Work Shifts: Recent Findings on Illnesses, Injuries, and Health Behaviors. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. [http://www.cdc.gov/niosh/docs/2004-143/]. Date accessed: July 26, 2012.

NIOSH [1985]. Occupational safety and health guidance manual for hazardous waste site activities. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 85-115. [http://www.cdc.gov/niosh/pdfs/85-115-a.pdf]. Date accessed: July 26, 2012.

NOAA [2011]. Quality controlled local climatological data: [http://cdo.ncdc.noaa.gov/qclcd/QCLCD]. Date accessed: July 26, 2012.

Selwyn AP, Braunwald E [2005]. Ischemic heart disease. In: Braunwald E, Fauci AS, Kasper DL, Hauser SL, Longo DL, Jameson JL, eds. Harrison's principles of internal medicine. 16th ed. New York: McGraw-Hill, pp. 1434-1444.

Siegel RJ [1997]. Myocardial hypertrophy. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia, PA: Lippencott-Raven, pp. 55–57.

References (cont.)

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

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

Stern S, de Luna AB [2009]. Coronary Artery Spasm: A 2009 Update. Circulation 119(18):2531-2534.

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.

USPSTF [2004]. U.S. Prevention Services Task Force. Screening for coronary heart diease: Recommendation Statement. Ann Intern Med 140(7):569–572.

van Gorselen EOF, Verheugt FWA., Meursing BTJ, Oude Ophuis AJM [2007]. Posterior myocardial infarction: the dark side of the moon. Neth Heart J 15(1): 16–21.

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.

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Thomas Hales, MD, MPH, led the investigation and authored 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

Physical Fitness Test (PFT)

The required elements of the PFT are:

1. A 1.5 mile run/jog/walk within 17 minutes and 15 seconds
2. One maximum bench press of 70% of the member's body weight
3. A vertical jump of at least 17 inches
4. A minimum of 20 push-ups
5. At least 25 sit-ups within 1 minute

Physical Fitness Test Procedures

1. One Repetition Maximum Bench Press

This is a maximum weight pushed from the bench press position and measures the amount of force the upper body can generate. It is important for performing tasks requiring upper body strength such as use of force situations. You will be expected to lift 70% of your body weight to meet the standard.

Equipment: Free Weights

Procedures:

A. Determine the amount of weight that the firefighter will have to lift to meet the standard. See Appendix F of this policy. The firefighter should be given this weight during the weigh in assessment phase of the testing process.

B. Two spotters will be used, one on each end of the bar.

C. Allow the firefighter to lift a lower weight a few times to get the feel for the exercise and to warm up.

You are allowed a 3 minute warm up if desired.

D. One of the following 3 methods may be used to lift the weight:

Appendix A (cont.)

- The firefighter is to push the weight that has been lowered to the point that the superior aspect of the upper arms is equal to or below his/her chest line by the spotters. The lift does not start from the up position but from the down position. Once the spotters have the weight in place the firefighter lifting the weight will state —ready. The spotters let go and the individual pushes the weight straight up until the elbows are locked. The spotters will then assist in replacing the bar to the rack.

- The person lifts the weight from the rack, in the up position, with the assistance of the spotters. With the assistance of the spotters the firefighter will lower the weight to the point that the superior aspect of the upper arms is equal to or below his/her chest line. Once the weight is lowered into position the person lifting will state —ready. The spotters will let go and the individual pushes the weight straight up until the elbows are locked. The spotters will then assist in replacing the bar to the rack.

- The firefighter lifts the weight from the rack in the up position, unassisted by the spotters. The spotters will remain in position for safety reasons in assisting if needed. The firefighter will lower the weight to the point that the superior aspect of the upper arms is equal to or below his/her chest line. The firefighter lifting pushes the weight straight up until the elbows are locked. The spotters will then assist in replacing the weight to the rack as needed.

Regardless of which method is used, the spotters will observe the superior aspect of the upper arms to make certain that they are equal to or below the chest line for the lift to count.
E. The firefighter lifting has the option of going directly to the required weight or can build up to it in ten or more pound increments. All lifts, including warm up lifts, will be assisted by the spotters and will be performed in the same manner.
F. The score for this test is the maximum (70%) or greater number of pounds lifted correctly in one repetition.

2. Vertical Jump
This is a measure of jumping or explosive power. It is important for tasks that require leg strength including climbing, lifting, jumping, carrying and when using various fire fighting tools including pike poles, ladders, axes and dragging of heavy objects.
Equipment: A vertical jump machine for measurement.
Procedures:
A. The firefighter stands in front of the machine and reaches as high as possible and touches the marker on the machine to mark his/her stand reach. This should be done standing flat footed with the elbow locked out and reaching straight up.
B. The firefighter jumps as high as possible and strikes one of the movable markers on the machine.
C. Scoring is measured in ½ inch increments on the machine. The required standard for this test is 17 inches.
D. The firefighter may use the best of three attempts. The firefighter is required to jump with both feet initially on the ground. The firefighter can jump from a standing position or they may start with one foot behind the other and jump. However, in both cases both feet must be firmly on the ground prior to jumping in the air.

3. Maximum Push-Up Test
This is a measure of the muscular endurance of the upper body extensor. It is important for use of force involving pushing motion. The score is the number of correct push-ups completed. There is no time

Appendix A (cont.)

limit for this test.
Equipment: Mat or semi-soft surface if available, such as carpet.
Procedure:
A. The firefighter assumes a front leaning position with the hands about shoulder width apart, or where they are most comfortable. However, the hands must be placed forward to the upper shoulder line. The back, buttocks and legs must be straight from head to heels. Begin the push-up by bending the elbows and lowering the entire body until the tops of the upper arms, shoulders, and lower back are aligned and parallel to the floor.
B. Return to the starting position by locking the elbows out. During the test the firefighter cannot rest the body on the ground.
C. If the firefighter does not keep the body straight or lock the elbows completely, then that repetition will not count.
D. The score is the maximum number of push-ups completed correctly. The minimum standard for this test is 20 push-ups.

4. One Minute Sit-Up Test
This test is a measure of the muscular endurance of the abdominal muscles. It is important for performing tasks that may involve the use of force and is important in maintaining good posture and minimizing lower back problems. The score is the number of sit-ups completed correctly in one minute.
Equipment: A mat or carpeted surface, and stopwatch.
Procedure:
A. The firefighter starts by lying on his/her back, knees bent, heels on the floor. The hands should be behind the head but fingers do not need to be interlocked. During the exercise the hands may go as far as the ears, but should not come off of the head.
B. A partner holds the feet down.
C. The firefighter then performs as many correct sit-ups as possible in one minute.
D. In the up position the firefighter should touch his/her elbows to the knees or on the upper leg as close to the knees as possible and then return to a full lying position before starting the next sit-up.
E. The firefighter cannot raise the buttocks from the ground and when returning to the down position the shoulder blades need to touch the ground.
F. The score is the total number of correct sit-ups in one minute, with 25 being the minimum standard.

5. 1.5 Mile Run/Walk
A measure of the cardiovascular endurance or aerobic power.
Equipment: A track and a stop watch.
Procedure:
A. The firefighter will warm up for at least 2 minutes. Longer warm up time may be given if desired.
B. The firefighter should be instructed to cover the distance as fast as possible.
C. At the command of —Go, time is started.
D. The score is the time required to cover the 1.5 miles. The minimum standard time for this test will be 17 minutes and 15 seconds.
E. A cool down period is required after this run of at least 5 minutes.
Note: A 5 minute rest period may be given between each testing station if requested.

Appendix B

Physical Ability Test

Job Related Simulated Test (JTST)
This simulation is representative of a firefighter's job-related physical tasks; therefore, the test will represent underlying physical conditioning levels needed to perform these duties. This is a cumulative timed event. All tasks are run consecutively through a course format and the cumulative time is recorded for the entire test.

The firefighter may not walk faster than a protocol pace (work like) during the test, no jogging will be permitted. The firefighter will be accompanied by a PFC acting as proctor during the entire test. The Job Task Simulated Test will consist of the following 10 activities and the minimum passing cumulative time will be 19 minutes and 00 seconds. All firefighters will complete the test wearing full turnouts and an SCBA (no mask) and there will be an option of two helmets; structural or wild land.

1. Initial Walk
The firefighter will begin by walking at a work like pace from the Ambulance 81 bay door to the sidewalk in front of the fire station. Continue walking on the sidewalk along 300 South to the Southeast corner of the rear parking lot of the station.

2. Ventilation
Using a 9 pound sledgehammer, the firefighter will begin striking the sled where directed. The sled will have to move the required distance (half the distance of the platform) where the firefighter will be directed to stop. This exercise simulates trenching or using an axe for cutting ventilation holes in a structure's roof.

3. High Rise Stair Climb
The firefighter will walk at a work like pace through the man door in the East Stairway. At the base of the stairs the firefighter will shoulder a 100 foot section of 2 ½ inch hose and then climb to the top of the stairs. Upon reaching the top landing the firefighter will keep the hose on the shoulder and will return to the bottom landing. The firefighter is to touch every step going both up and down and one hand should maintain in contact with the handrail for stability. Upon reaching the ground level the firefighter will place the hose on the floor.

4. Equipment Hoist
The firefighter will climb the stairs to the top landing and then proceed up the ladder to the roof area. They will then pull a rope using a hand over hand method which will raise a 50 foot section of 1¾ inch hose. Once the hose roll reaches the top of the wall, the firefighter will lower the hose to the ground in a controlled manner, again using the hand over hand method. The firefighter will return down the stairs to the ground floor.

5. Equipment Carry / Hydrant
Outside the stairwell the firefighter will pick up the hydrant bag containing one 5 inch gate valve and a hydrant wrench and will carry the bag south across parking lot to the training hydrant. The firefighter will fully open and then close the hydrant, this will take approximately 24 turns in each direction. The hydrant caps will not have to be removed. Leaving the tools there the firefighter will then proceed to the ladder raise as directed.

6. Ladder Raise
The firefighter will pick up the tip of the 24 foot ladder and raise it hand over hand above the

Appendix B (cont.)

head until the ladder is flat against the wall. The firefighter will then walk back, lowering the ladder hand over hand until it reaches the ground. The butt of the ladder will be placed against the wall of the building and should remain there during this task. The firefighter will then proceed to the hose drag area.

7. Hose Drag
The firefighter will drag 150 feet of charged 1¾ inch hose from the station bay door East, across the parking lot, 100 feet. The drag will continue to the South, towards the sidewalk another 50 feet. When directed the firefighter will open and then close the nozzle before placing the nozzle on the ground. The firefighter will then proceed to the tool crawl area.

8. Tool Crawl
The firefighter will enter the bay door near the stair tower where they will pick up the tool (a halligan and axe combo). They will crawl with the combo tool 75 feet using a right hand search method near the wall until they reach the phone shelf near the front of the station. Do not enter into the turnout room. Leave the tool as directed and walk to the Southeast corner of the back parking lot for the victim rescue.

9. Victim Rescue
The firefighter will pick up the victim dummy and drag it 100 feet North across the parking lot towards the tennis courts. The victim dummy can be dragged however the firefighter feels is most convenient and efficient. The leg muscles should be used to lift and drag the victim dummy, rather than bending over and using back muscles. The firefighter will walk through the ambulance bay door to the pike pole simulator on the South bay wall.

10. Ceiling Breech and Pull
Using the short pike pole the firefighter will push up the weighted ceiling door prop 10 times. The firefighter will then move the pike pole to the pull down hook on the prop and will fully pull this prop 10 times. This exercise will be repeated three (3) times.

The entire simulation will end at this time as directed.

Appendix C

Autopsy Findings

Cardiac

- Mild cardiomegaly; heart weighing 450 grams (g) (predicted normal weight is 421 g with upper 95th percentile of 546 g as a function of sex, age, and body weight) [Silver and Silver 2001]
- Concentric left ventricular hypertrophy
  - left ventricular free wall = 1.7 cm
  - interventricular septum = 1.9 cm (normal by autopsy 0.76–0.88 cm [Colucci and Braunwald 1997]; normal by echocardiography 0.6–1.0 cm [Connolly and Oh 2012])
  - right ventricular free wall = 0.4 cm
- Coronary Arteries
  - Widely patent without evidence of significant artherosclerosis or thrombosis
- Heart muscle
  - An area of hemorrhage in the posterior papillary msucles suggestive of ischemia/ infarction
- Microscopic Evaluation
  - Hemorrhage and neutrophilic infiltration of the posterior wall of the left ventricle (consistent with a focal acute myocardial infarction (e.g., heart attack).
  - Myocyte hypertrophy with enlarged nuclei (consistent with changes due to hypertension)

Lungs

- Pulmonary edema
- No evidence of pulmonary embolus
- No evidence of mucous plugs or signs of severe chronic asthma

Kidneys - Microscopic Evaluation

- Hyaline arteriolosclerosis (change consistent with longstanding hypertension)
- Glomerulosclerosis (changes typically caused by diabetes mellitus)

References

Colucci WS, Braunwald E [1997]. Pathophysiology of heart failure. In: Braunwald, ed. Heart disease. 5th ed. Philadelphia, PA: W.B. Saunders Company, p. 401.

Connolly HM, Oh JK [2012]. Echocardiography. In: Bonow RO, Mann DL, Zipes DP, Libby P, Braunwald E, eds. Heart disease: a text of cardiovascular medicine. 9th ed. Vol. 1. Philadelphia, PA: Elsevier Saunders, p. 216.

Silver MM and Silver MD [2001]. Examination of the heart and of cardiovascular specimens in surgical pathology. In: Silver MD, Gotlieb AI, Schoen FJ, eds. Cardiovascular pathology. 3rd ed. Philadelphia, PA: Churchill Livingstone, pp. 8–9.