Death in the line of duty...

Driver/Engineer Suffers Sudden Cardiac Death at Scene of Motor Vehicle Crash – Georgia

Executive Summary

On March 7, 2013, a 49-year-old male career driver-engineer ("the Engineer") reported for duty at 0730 hours for his 24-hour shift. In the afternoon, the Engineer completed a 25-minute training session for an upcoming physical ability test. Approximately 25 minutes later, his engine was dispatched to a motor vehicle crash. At the scene, the Engineer was assisting the ambulance paramedics with a stretcher when he suddenly collapsed. Cardiopulmonary resuscitation (CPR) and advanced life support (ALS), including cardiac monitoring, multiple defibrillation attempts, intubation, and intravenous line placement, began immediately. Despite CPR and ALS for almost an hour on the scene, in transport, and at the hospital, the Engineer died. The death certificate and the autopsy listed "sequelae of atherosclerotic cardiovascular disease" as the cause of death. Given the Engineer's underlying cardiovascular disease, NIOSH investigators concluded that the physical exertion of the training session and the stress of responding to the motor vehicle crash most likely triggered an arrhythmia that resulted in his sudden cardiac death.

NIOSH investigators offer these recommendations to strengthen the fire department's (FD's) comprehensive safety and health program and to prevent future events.

Modify the frequency of exercise stress tests required by the FD for annual medical evaluations.

Modify the formula used by the FD to estimate a fire fighter's aerobic capacity.

Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Ensure that fire fighters are 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.

Introduction & Methods

On March 7, 2013, a 49-year-old male career driver/engineer died after physical ability training and responding to a motor vehicle crash. NIOSH contacted the affected fire department on March 11, 2013, to gather information and on June 18, 2013, to initiate the investigation. On June 24, 2013, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program investigated the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire chief
- FD training chief
- Crew member
- Engineer's family

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD annual report for 2012
- FD incident report
- Emergency medical service (ambulance) report
- Hospital emergency department report
- Death certificate

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Introduction & Methods (cont.)

- Autopsy
- FD medical evaluation records
- Primary care physician records (the Engineer was seen in the city occupational medicine clinic)

Investigative Results

Incident. On March 7, 2013, the Engineer reported to his fire station at 0730 hours for a 24-hour shift (0800 hours to 0800 hours). As the Engineer of Engine 53, he conducted truck and equipment checks prior to performing station duties. During the morning hours, Engine 53 was dispatched and responded to one medical call.

At approximately 1530 hours, the Engineer (wearing turnout gear) and a crew member began training for the FD's annual physical ability test. Components of the actual test are included in Appendix A, and the Engineer's training activities are included in Appendix B. The physically demanding training ended at approximately 1600 hours, and the Engineer and his crew member rested and hydrated.

At 1624 hours, Engine 53 was dispatched to a motor vehicle crash. Arriving on the scene at 1629 hours, the crew found the ambulance paramedics treating a person with minor injuries. Six minutes later, as the Engineer was assisting with a stretcher, he collapsed without warning (1635 hours).

Crew members and paramedics assessed the Engineer and found him unresponsive, not breathing, and pulseless. CPR was begun as a cardiac monitor was applied. The monitor revealed ventricular fibrillation, and a shock was administered without a change in his clinical status. The Engineer was intubated with tube placement verified by capnography [Neumar et al. 2010]. An intravenous line was placed through which cardiac resuscitation medications were administered. Two additional shocks were administered as the ambulance departed the scene at 1649 hours en route to the nearest hospital.

The ambulance arrived at the hospital's emergency department at 1654 hours. In the emergency department, CPR and ALS efforts continued, including eight additional defibrillation attempts (shocks) over 39 minutes without a change in the Engineer's clinical status. At 1733 hours the Engineer was pronounced dead by the attending physician, and resuscitation efforts were discontinued.

Medical Findings. The death certificate and the autopsy, both completed by the county medical examiner's office, listed "sequelae of atherosclerotic cardiovascular disease" as the cause of death. Pertinent findings from the autopsy are listed in Appendix C.

In May 2010 the Engineer was diagnosed with hyperlipidemia and hypertriglyceridemia that were treated with weight management and a low triglyceride diet. His most recent lipid values in August 2012 included a cholesterol of 144 milligrams per deciliter [mg/dL] [normal is 100–199], triglycerides of 169 mg/dL [normal is 0–149], a high density lipoprotein (HDL) of 30 mg/dL [normal is >39], and a low density lipoprotein (LDL) of 82 [normal is 0–99].

As part of the FD's annual medical evaluation program, the Engineer underwent an annual submaximal treadmill exercise test using the Gerkin protocol [Gerkin et al.1997]. In 2010, he exercised for 6 minutes and 30 seconds before stopping because he reached 85% of his target heart rate (220

Investigative Results (cont.)

minus age × 0.85 = 148 beats per minute). He did not complain of angina, had a normal blood pressures response, and showed no sign of ischemia on his electrocardiogram (EKG). However, his EKG tracing showed an arrhythmia (ventricular couplet). His treadmill test lasted for 7 minutes in 2011 and 6 minutes in 2012, with no angina, normal blood pressure response, and normal EKG with no arrhythmias. During these treadmill exercise tests, the medical clinic estimated his aerobic capacity (milliliters per kilogram per minute [mL/kg/min]) to be 50 in 2010, 48.6 in 2011, and 44.1 in 2012.

The Engineer was 73 inches tall and weighed 265 pounds, giving him a body mass index of 35 kilograms per meter squared. A body mass index > 30.0 kilograms per meter squared is considered obese [CDC 2011]. The Engineer never reported symptoms suggestive of coronary heart disease (CHD). He walked daily for exercise.

Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 6 fire stations with 131 career uniformed personnel serving 62,000 residents in a geographic area of 22 square miles. In 2012, the FD responded to 10,592 calls including 330 fires, 6,330 medical calls, 1,530 good intent calls, 1,241 service calls, and 1,161 other calls. Engine 53 responded to 728 calls (6.8%).

Employment and Training. The FD requires new full-time fire fighter applicants to be 18 years of age, have a valid state driver's license, have a high school diploma or a general equivalency diploma, pass a written test, pass a background check, pass a five-station fitness evaluation and a six-station candidate physical agility test (described below), and pass an interview with the fire chief prior to receiving a conditional job offer. The successful applicant must then pass a preplacement medical evaluation (described below), a polygraph, and a psychological evaluation prior to being hired. The new hire is placed in a 3-month training program to be trained as a Fire Fighter 1. At the end of the training, the new hire must pass a state written test to become fully certified as Fire Fighter 1. The new hire is on probation for 1 year and is placed on a shift working 24 hours on-duty/48 hours off-duty. The Engineer was certified as a Fire Fighter 1 and 2, Driver/Operator, EMT-Intermediate, and Hazardous Materials Technician. He had 23 years of fire fighting experience including 18 years in this FD.

Physical Fitness and Physical Agility Tests. Candidates are given a preparation/training guide prior to attempting the tests. Both tests are timed evaluations consisting of fitness (vertical jump, sit-up, push-up, 300-meter run, 1.5-mile run) and physical ability (stair climb, ladder extension, ventilation exercise, hose advance, rescue drag, and ladder removal/replacement). Additional detail is provided in Appendix D.

Members are also required to pass an untimed physical agility test annually (Appendix A). The Engineer completed his last physical ability test in May 2012.

Preplacement and Annual Medical Evaluations. Since 2002, the Engineer had annual FD medical evaluations. In 2010, the FD changed contract medical providers to the current provider. The FD requires preplacement medical evaluations for all applicants and annually for all members. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)

Description of the FD (cont.)

- Blood tests: complete blood count, lipid panel
- Urinalysis
- Spirometry
- Resting EKG
- Submaximal exercise stress test (Gerkin protocol)
- Hearing (audiometric) test
- Vision screen
- Fitness test (muscular endurance [sit-ups and push-ups]) and flexibility
- Random urine drug testing (candidates only)

The evaluations are performed by a city-contracted physician. Once this evaluation is completed, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the city (for candidates) or the FD (for members). Medical clearance to wear a respirator and an annual self-contained breathing apparatus facepiece fit test are also required.

Members injured on duty are evaluated by the attending emergency department physician or the workers' compensation physician, who forwards their findings to the FD who makes the final determination regarding return to work. Members who are ill and miss work for 36 hours or 3 occurrences of sick leave usage within 1 year must see their personal physician, who provides a medical clearance opinion to the FD, which makes the final determination regarding return to work. Members who miss work for 36 hours may also have to complete a physical agility test.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program. Approximately 85% of the members participate while on duty or off duty. Exercise equipment is available in all fire stations. The Engineer exercised by walking 30 minutes every day in an effort to start participating in the FD's wellness/fitness program.

Discussion

Atherosclerotic Coronary Heart Disease. In the United States, atherosclerotic CHD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of CHD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [Greenland et al. 2010; NHLBI 2012; AHA 2013]. The Engineer had three CHD risk factors (age older than 45, male gender, and obesity).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques.

Establishing a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, an EKG did not reveal a heartbeat, cardiac enzymes were not tested, and no coronary artery thrombus was identified at autopsy. Given that heart attacks can occur without a coronary thrombus, it is possible that the Engineer had a heart attack [Davies 1992; Farb et al. 1995]. Because the Engineer reported no angina (i.e., chest pain), it is more likely his sudden death was due to a cardiac arrhythmia.

Primary Arrhythmia. A primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) was

Discussion (cont.)

probably responsible for the Engineer's sudden cardiac death. Risk factors for arrhythmias include cardiac disease, heart attack, sleep apnea, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [AHA 2012; Mayo Clinic 2013]. The Engineer's autopsy revealed his moderate atherosclerotic CHD, cardiomegaly, and left ventricular hypertrophy (discussed below). These cardiac conditions increase the risk for primary arrhythmia [AHA 2012]. In addition, the Engineer reported snoring on the FD's "review of symptoms" checklist completed during his annual medical evaluation. This symptom, coupled with his body mass index of 35 to 39.7 during the years 2010–2013, suggests a diagnosis of obstructive sleep apnea [Gurubhagavatula et al. 2004; Somers et al. 2008]. Sleep apnea has been associated with sudden cardiac death [Ludka et al. 2011; Gami et al. 2013] as well as other cardiovascular conditions such as hypertension, heart failure, strokes, arrhythmias, heart attacks, and pulmonary hypertension [Somers et al. 2008].

In addition to medical conditions, sudden cardiac death has also been linked to heavy physical exertion [Albert et al. 2000]. Among fire fighters, sudden cardiac events have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The Engineer's physical ability test training session would have expended about 12 metabolic equivalents, which is considered heavy physical activity [Gledhill and Jamnik 1992; Ainsworth et al. 2011].

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the Engineer was found to have left ventricular hypertrophy and an enlarged heart (cardiomegaly). These conditions increase the risk for sudden cardiac death [Levy et al. 1990]. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing hypertension, a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. The Engineer did not have hypertension or significant valve problems, but may have had chronic ischemia associated with his moderate atherosclerotic CHD noted at autopsy (Appendix C).

In summary, NIOSH investigators conclude the Engineer's sudden cardiac death was probably due to an arrhythmia triggered either by his underlying undiagnosed CHD and/or the physical exertion associated with his physical ability test training session.

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2013]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Engineer's CHD was not known until autopsy; therefore, there was no reason to restrict his work on the basis of CHD. Exercise stress tests can be used to screen for and identify occult CHD. However, recommendations for conducting exercise stress tests on asymptomatic individuals without known heart disease are varied. The following paragraphs summarize the positions of widely recognized organizations on this topic.

NFPA 1582, a voluntary industry standard, recom-

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mends an exercise stress test performed "as clinically indicated by history or symptoms" and refers the reader to its Appendix A [NFPA 2013]. 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 (i.e., 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 (CAD)
- one or more risk factors for CAD (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 CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology/American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA guideline states the evidence is "less well established" (Class IIb) for the following groups:

- 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 impairment might jeopardize public safety (e.g., fire fighters)
    - who are at high risk for CAD 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 driver's 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 CHD
- 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 CHD events. For individuals at increased risk for CHD 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."

Given that the Engineer had none of the CHD risk factors noted by the above organizations, a symptom limiting exercise stress test was not indicated.

Discussion (cont.)

Sleep Apnea. In May 2012 the Engineer identified on the FD annual medical evaluation questionnaire that he snored when sleeping on his back. This symptom, coupled with his BMI of >35, suggests a diagnosis of sleep apnea [Gurubhagavatula et al. 2004; Somers et al. 2008]. NFPA 1582 considers untreated obstructive sleep apnea as a condition that could impair a fire fighter's ability to perform essential job tasks. A formal sleep study is indicated to determine the presence and severity of the condition [Somers et al. 2008; NFPA 2013].

Recommendations

The following recommendations are offered to strengthen the FD's comprehensive safety and health program and to prevent future events.

Recommendation #1: Modify the frequency of exercise stress tests required for annual medical evaluations.

The FD does an exercise stress test on all applicants during their preplacement medical evaluation, regardless of the applicant's age, number of CHD risk factors, or severity of CHD risk factors. While this test has value to ensure the candidate has the aerobic capacity needed to be a fire fighter, its use on individuals at low risk for CHD is an unnecessary expense for the FD [Gibbons et al. 2002].

Recommendation #2: Modify the formula used by the FD to estimate a fire fighter's aerobic capacity.

The submaximal exercise stress tests administered by the FD (Gerkin protocol) are similar to the fitness evaluation tests recommended by the 2000 edition of the Wellness Fitness Initiative and reprinted in the appendix of NFPA 1582, 2007 edition [IAFF/IAFC 2000, NFPA 2007]. However, subsequent testing of the Gerkin protocol has shown that it overestimates aerobic capacity [Mier and Gibson 2004; Tierney 2010]. As a result, the equation to predict aerobic capacity from a submaximal treadmill test using the Gerkin protocol was revised in the recent edition of the Wellness Fitness Initiative and NFPA 1582 [IAFF/IAFC 2008, NFPA 2013]. Using this new formula, the Engineer's estimated aerobic capacity was between 33 and 34 mL/kg/min. The 2013 edition of NFPA 1582 recommends that fire fighters with an aerobic capacity between 8 and 12 metabolic equivalents (28–41 mL/kg/min) be counseled to improve their fitness and be prescribed an exercise program [NFPA 2013].

Recommendation #3: Phase in a mandatory comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in Firefighter Fitness: A Health and Wellness Guide [IAFF, IAFC 2008; NFPA 2008b; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Chapman 2005; Mills et al. 2007; Pelletier 2009; Baicker et al. 2010]. Fire service health promotion programs have been shown to reduce CHD risk factors and improve fitness levels, with mandatory programs

Recommendations (cont.)

showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than $1 million 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 nonoccupational healthcare costs [Kuehl et al. 2013]. While most FD members participate in exercise, the FD has a voluntary wellness/fitness program. NIOSH recommends a formal, mandatory wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #4: Ensure that fire fighters are 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.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008; NFPA 2013]. 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. 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 fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. The FD utilizes a city-contracted physician for medical evaluations while on-the-job injuries are treated by a workers' compensation physician and lengthy illnesses are treated by the member's primary care physician. NIOSH investigators recommend all these medical evaluations be coordinated through the FD (or contract) physician.

References

AHA [2012]. Understand your risk for arrhythmia. Dallas, TX: American Heart Association. [http://www.heart.org/HEARTORG/Conditions/Arrhythmia/UnderstandYourRiskforArrhythmia/Understand-Your-Risk-for-Arrhythmia_UCM_002024_Article.jsp]. Date accessed: July 2013.

AHA [2013]. Understand your risk of heart attack. Dallas, TX: American Heart Association. [http://www.heart.org/HEARTORG/Conditions/HeartAttack/UnderstandYourRiskofHeartAttack/Understand-Your-Risk-of-Heart-Attack_UCM_002040_Article.jsp]. Date accessed: July 2013.

Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS [2011]. Compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc *43*(8):1575–1581.

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.

References (cont.)

Baicker K, Cutler D, Song Z [2010]. Workplace wellness programs can generate savings. Health Affairs *29*(2):1–8.

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.

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 2013.

CDC (Centers for Disease Control and Prevention) [2011]. BMI – Body Mass Index. [http://www.cdc.gov/healthyweight/assessing/bmi/index]. Date accessed: July 2013.

Chapman LS [2005]. Meta–evaluation of worksite health promotion economic return studies: 2005 update. Am Health Promot *19*(6):1–11.

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*(7):1701–1709.

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

Gami AS, Olson EJ, Shen K, Wright RS, Ballman KV, Hodge DO, Herges RM, Howard DE, Somers VK [2013]. Obstructive sleep apnea and the risk of sudden cardiac death: a longitudinal study of 10,701 adults. J Am Coll Cardiol 2013. [http://www.cardiosource.org/Science-And-Quality/Journal-Scan/2013/06/Obstructive-Sleep-Apnea-and-the-Risk-of-Sudden-Cardiac-Death.aspx]. Date accessed: July 2013.

Gerkin R, Kelley P, Perry R [1997]. Correlation of VO2max during maximal treadmill stress testing with VO2 at 85% predicted maximal heart rate: A retrospective review of the Phoenix fire department treadmill protocol. Technical report to the medical director of the Phoenix Fire Department Medical Center.

Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr., Antman EM, Alpert JS, Faxon DP, Fuster V, Gregoratos G, Hiratzka LF, Jacobs AK, Russell RO, Smith SC Jr. [2002]. ACC/AHA 2002 guideline update for exercise testing: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation *106*(14):1883–1892.

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

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References (cont.)

Greenland P, Alpert JS, Beller GA, Benjamin EJ, Budoff MJ, Fayad ZA, Foster E, Hlatky MA, Hodgson JM, Kushner FG, Lauer MS, Shaw LJ, Smith SC Jr., Taylor AJ, Weintraub WS, Wenger NK [2010]. 2010 ACCF/AHA guideline for assessment of cardiovascular risk in asymptomatic adults: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation *122*(25):e584–e636.

Gurubhagavatula I, Maislin G, Nkwuo JE, Pack AL [2004]. Occupational screening for obstructive sleep apnea in commercial drivers. Am J Respir Crit Card Med *170*(4):371–376.

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

IAFF, IAFC [2008]. The fire service joint labor management wellness/fitness initiative. 3rd ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ Health: a global access science source. 2:14. [http://www.ehjournal.net/content/2/1/14]. Date accessed: July 2013.

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

Kuehl KS, Elliot DL, Goldberg L, Moe EL, Perrier E, Smith J [2013]. Economic benefit of the PHLAME wellness programme on firefighter injury. Occ Med *63*(3):203–209.

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

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

Ludka O, Konecny T, Somers V [2011]. Sleep apnea, cardiac arrhythmias, and sudden death. Texas Heart Institute J *38*(4):340–343.

Mayo Clinic [2013]. Heart arrhythmias. [http://www.mayoclinic.com/health/heart-arrhythmias/DS00290/METHOD=print&DSECTION=all]. Date accessed: July 2013.

Meyerburg RJ, Castellanos A [2008]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Fauci AS, Braunwald E, Kasper DL, Hauser SL, Longo DL, Jameson JL, Loscalzo J, eds. Harrison's principles of internal medicine. 17th ed. New York: McGraw-Hill, pp. 1707–1713.

Mier CM, Gibson AL [2004]. Evaluation of a treadmill test for predicting the aerobic capacity of firefighters. Occup Med *54*(6):373–378.

References (cont.)

Mills PR, Kessler RC, Cooper J, Sullivan S [2007]. Impact of a health promotion program on employee health risks and work productivity. Am J Health Promot *22*(1):45–53.

NFPA [2007]. 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.

NFPA [2013]. Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association. NFPA 1582.

NHLBI [2012]. Who is at risk for coronary artery disease? National Heart, Lung, and Blood Institute. [http://www.nhlbi.nih.gov/health/health-topics/topics/cad/atrisk.html]. Date accessed: July 2013.

NIOSH [2007]. NIOSH alert: preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2007-133. [http://www.cdc.gov/niosh/docs/2007-133/]. Date accessed: July 2013.

Neumar RW, Otto CW, Link MS, Kronick SL, Shuster M, Callaway CW, Kudenchuk PJ, Ornato JP, McNally B, Silvers SM, Passman RS, White RD, Hess EP, Tang W, Davis D, Sinz E, Morrison LJ [2010]. Part 8: Adult advanced cardiovascular life support. 2010 American Heart Association Guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Dallas, TX: American Heart Association.

Pelletier KR [2009]. A review and analysis of the clinical and cost–effectiveness studies of comprehensive health promotion and disease management programs at the worksite: update VII 2004–2008. J Occup Environ Med *51*(7):822–837.

Schneider EL [2010]. Firefighter fitness: a health and wellness guide. New York: Nova Science Publishers.

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

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

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References (cont.)

Somers VK, White DP, Amin R, Abraham WT, Costa F, Culebras A, Daniels S, Floras JS, Hunt CE, Olson LJ, Pickering TG, Russell R, Woo M, Young T [2008]. Sleep Apnea and Cardiovascular Disease: An American Heart Association/ American College of Cardiology Foundation Scientific Statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing Council. J Amer Coll Cardiol *52*(8):686–717.

Tierney MT, Lenar D, Stanforth PR, Craig JN, Farrar RP [2010]. Prediction of aerobic capacity in firefighters using submaximal treadmill and stairmill protocols. J Strength Cond Res *24*(3):757–764.

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

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

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-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

Annual Member FD Physical Agility Test
This test is mandatory for all members. The test is not timed. The person wears full bunker gear (coat, pants, boots, helmet, and gloves) but no self-contained breathing apparatus.

Task 1: Stair Climb. Go up and down the 2½-flight staircase three times. One foot must touch the top and bottom landings. Using the handrails going up and down is permitted. Skipping steps is permitted while going up the steps but the participant must touch each step while going down the steps.

Task 2: Ceiling Pulls. Perform this evolution 30 times. The pike pole must touch the floor each time.

Task 3: Hang. Grab the overhead bar, pull up, and hang with feet off the floor for 25 seconds.

Task 4: Patient Lift. Deadlift the 115-pound weight 10 times. Lift with your legs and keep your back straight.

Task 5: Repeat Stair Climb (see Task 1).

Task 6: Hose Roll Carry. Starting at the beginning of the tile in the hallway, proceed through the door to the outside, ending 120-feet from the start. Carry a 3″ hose roll in each hand (two rolls).

Task 7: Tire Pull. Use the small-size tractor tire. The tire will be pulled 60 feet from the starting line to the finish line.

Task 8: Sledge Hammer Hits on Tire. Strike the tire 15 times. The head of the plastic sledge hammer must be lifted above the plane of the shoulders during each swing. The participant may stand on the tire or on the ground. The tire does not have to be moved for this exercise to count.

Task 9: Rescue Drag. Drag the rescue dummy 60 feet. The 100-pound dummy is the one with hose for legs. Lay the dummy on the ground.

Task 10: Repeat Hose Roll Carry (see Task 6).

Task 11: Repeat Stair Climb (see Task 1).

Task 12: Hose Pack Cleans. Lift and lower the 2½-inch diameter rolled hose 15 times. The hose must touch the floor each time. Lay the hose down.

Task 13: Dips. Using the dip bar, hold upright dip position for 25 seconds.

Task 14: Repeat Stair Climb (see Task 1). After descent, the test is stopped. Proceed to rehabilitation.

Appendix B

Engineer's Physical Agility Test Practice

- Walk up and down one flight of stairs 12 times to simulate high rise fire fighting.
- Hang from pull-up bar for 25 seconds.
- Deadlift 135 pounds ten times to simulate lifting at a fire.
- 30 pike pole pulls to simulate pulling a ceiling on fire.
- Walk up and down one flight of stairs 12 times to simulate high rise firefighting.
- Carry two 45-pound dumbbells 50 feet.
- Drag the 150-pound "victim" 25 feet to simulate rescue in a fire.
- 15 sledgehammer hits to a tire to simulate door breaching in a fire.
- Tire drag with hose 25-feet to simulate pulling hose at a fire.
- Carry two 45-pound dumbbells 50 feet.
- Walk up and down one flight of stairs 12 times to simulate high rise firefighting.
- High rise pack on and off shoulder 15 times to simulate high rise firefighting.
- Perform five 25-second static dips.
- Walk up and down one flight of stairs 12 times to simulate high rise firefighting.

Driver/Engineer Suffers Sudden Cardiac Death at Scene of Motor Vehicle Crash – Georgia

Appendix C

Autopsy Findings

- Heart disease
  - Coronary artery atherosclerosis
    - Moderate (70%) focal narrowing of the left anterior descending coronary artery
    - Moderate (60%) focal narrowing of the right coronary artery
    - No evidence of a coronary artery thrombus (blood clot)

  - Cardiomegaly (enlarged heart; heart weighed 589 grams [g]; predicted normal weight is 410 g [ranges between 311 g and 541 g as a function of sex, age, and body weight]) [Silver and Silver 2001]

  - Left ventricular hypertrophy
    - Left ventricle and interventricular septum thickened (1.4 centimeter [cm] each)
      - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
      - Normal by echocardiographic measurement is 0.6–1.0 cm [Connolly and Oh 2012]
      - Petechial hemorrhages in the anteromedial basal half and mid-portions of the heart
      - Microscopic: perivascular fibrosis of the left ventricular wall
  - Right ventricular dilatation (cavity diameter 7.5cm)
  - Bilateral atrial dilatation
- Valve abnormalities
  - Aortic valve has fenestrations (considered clinically insignificant by the pathologist)
  - Pulmonary valve has an anomalous trabeculae carneae (considered clinically insignificant by the pathologist)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative.

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, 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.

Appendix D

Candidate Physical Fitness/Physical Ability Test
These tests are mandatory for all candidates. The tasks represent essential job tasks for public safety employees as described by The Cooper Institute [The Cooper Institute 2011]. The person wears gym shorts, T-shirt, and athletic shoes during the fitness evaluation and wears gloves, helmet, and a self-contained breathing apparatus (without the mask) during the physical ability test. The candidate is allowed 7 minutes to complete the physical ability test and may not run during the test. Time will begin at the start of the first exercise and shall stop when the candidate completes the last exercise. Time will not stop during the test.

Fitness Evaluation
Task 1: Vertical Jump. The candidate must jump up at least 16.5 inches. Upon completion, the candidate will rest for 2 minutes and proceed to the sit-up test.

Task 2: Sit-up. The candidate must complete 27 sit-ups in one minute. Upon completion, the candidate will rest and then proceed to the upper body strength test.

Task 3: Push-up. The candidate must complete 18 continuous push-ups. Upon completion, the candidate will rest and then proceed to the 300-meter run test.

Task 4: 300-meter run. The candidate must complete the 300-meter run within 68 seconds. Upon completion, the candidate will rest and then proceed to the 1.5-mile run.

Task 5: 1.5-mile run. The candidate must complete the 1.5-mile run within 15:20 minutes. Upon completion, the candidate will rest, obtain the necessary gear, and proceed to the physical ability test area.

Physical Agility Test
Task 1: Stair Climb. The candidate, given two rolled 500-foot sections of 1¾-inch diameter hose and a multi-story structure, shall carry the hose section up one flight of stairs to the second floor and then return to the starting point with the hose. The candidate must use each step while climbing or descending the stairway. The candidate will proceed immediately to Task 2.

Task 2: Ladder Extension. The candidate, given a 24-foot aluminum extension ladder in a securely supported vertical position, must completely extend the ladder's fly section (top section). The candidate must then lower the fly section in a controlled fashion to the starting position and proceed immediately to Task 3.

Appendix D (cont.)

Task 3: Ventilation Exercise. Given a fire department sledge hammer and a Kaiser sled, the candidate will use the hammer to strike the weighted "sled" section of the Kaiser machine a minimum of 20 times. No hooking or dragging of the sled is permitted. Only good clean strikes by the mallet to the sled are allowed. The hammer must be raised completely above the shoulder line to simulate a chopping motion as if cutting a ventilation hole. The candidate will place the hammer on the ground and immediately proceed to Task 4.

Task 4: Hose Advance. The candidate, given a charged (75 psi nozzle pressure) 100-foot 1¾-inch hoseline, shall pick up the nozzle and advance the pressurized hoseline for a distance of 50 feet. After reaching the destination, the candidate shall lay the hose on the ground and proceed immediately to Task 5.

Task 5: Rescue Drag. The candidate, given a 165-pound dummy on a level surface, shall drag the dummy a distance of 50 feet. Lay the dummy on the ground and proceed immediately to Task 6.

Task 6: Ladder Removal/Replacement. The candidate, given a 14-foot roof ladder placed in a horizontal position at a height of 5 feet and with the ladder rungs in a vertical position, shall lift the entire ladder from its support and place it on the ground then pick the entire ladder up and return it to its original position. The time keeper will record the time.

References

The Cooper Institute [2011]. [http://cooperinstitute.org/pub/products.cfm?actionxm=Detail&item_id=4178]. Date accessed: July 2013.