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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

January 4, 2008

Engineer Suffers Sudden Cardiac Death After Responding to Three Emergency Calls and Performing Physical Fitness Training – Arizona

SUMMARY

On June 4, 2007, a 53-year-old male career Engineer participated in physical fitness training as part of the Fire Department's physical fitness program. During the fitness period, his engine company was dispatched to three calls. After the third call, and after completing the fitness training, the crew drove to a restaurant for lunch. While ordering food the Engineer gave his money to a crew member and walked outside to call his wife. As he walked outside, he collapsed. A customer entered the restaurant and alerted the fire fighters that "someone was down on the sidewalk." The crew members found the Engineer unresponsive, with no pulse, and with agonal breathing (1343 hours). Dispatch was notified, cardiopulmonary resuscitation (CPR) and advanced life support were begun, an ambulance responded, and the Engineer was transported to the local hospital's Emergency Department. Inside the Emergency Department, advanced life support treatment continued with no improvement in the Engineer's condition. The attending physician pronounced the Engineer dead at 1427 hours and resuscitation efforts were discontinued. The death certificate and autopsy (completed by the Medical Examiner) listed "coronary artery heart disease" as the cause of death. The NIOSH investigator concluded that the physical stress of responding to three alarms and participating in vigorous exercise, coupled with the Engineer's underlying coronary artery disease, triggered his sudden cardiac death.

The NIOSH investigator offers the following recommendation to prevent similar incidents.

- ***Ensure annual medical evaluations that include electrocardiograms (EKGs) and exercise stress tests are performed for fire fighters at risk for coronary artery disease.***

The following recommendation is made to enhance safety and health. It did not contribute to the Engineer's death.

- ***Eliminate or reduce the frequency of periodic chest x-rays in asymptomatic fire fighters, unless clinically indicated.***

The Fire Fighter Fatality Investigation and Prevention Program is conducted by the National Institute for Occupational Safety and Health (NIOSH). The purpose of the program is to determine factors that cause or contribute to fire fighter deaths suffered in the line of duty. Identification of causal and contributing factors enable researchers and safety specialists to develop strategies for preventing future similar incidents. The program does not seek to determine fault or place blame on fire departments or individual fire fighters. To request additional copies of this report (specify the case number shown in the shield above), other fatality investigation reports, or further information, visit the Program Website at

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Engineer Suffers Sudden Cardiac Death After Responding to Three Emergency Calls and Performing Physical Fitness Training – Arizona

INTRODUCTION and METHODS

On June 4, 2007, a 53-year-old male career Engineer died after performing physical fitness training. NIOSH was notified of this fatality on June 6, 2007 by the United States Fire Administration. NIOSH contacted the affected Fire Department on June 6, 2007 to obtain further information, and on July 3, 2007 to initiate the investigation. On July 16, 2007, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Arizona to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Assistant Fire Chief
- Deputy Fire Chief for Safety
- Assistant Fire Marshal
- Division Chief for Training
- Fire Department Medical Director
- Fire Department Personnel Officer
- Fire Protection Engineer for Research and Planning
- Fire Department Industrial Hygienist
- International Association of Fire Fighters (IAFF) Local President
- Crew members
- Engineer's spouse

NIOSH personnel reviewed the following documents:

- Fire Department incident reports
- 9-1-1 dispatch records
- Witness statements
- Fire Department training records
- Fire Department annual 2006 response report
- Fire Department standard operating guidelines
- Ambulance report
- Death certificate
- Autopsy report
- Primary care physician records

INVESTIGATIVE RESULTS

Incident. On June 4, 2007, the Engineer arrived at his fire station (Station 37) for duty at 0745 hours; his shift began at 0800 hours. From 0800 hours to 0845 hours, the Engineer checked the equipment on his apparatus (Engine 37) and vacuumed the apparatus bay. At 0845 hours, Engine 37 and its crew departed the station en route to a local gym to play basketball as part of the Fire Department's physical fitness program. The fire fighters arrived at the gym at 0920 hours and began playing basketball.

Engine 37 was dispatched to medical calls at 0928 hours, 1047 hours, and 1155 hours. At these calls, the Engineer carried medical equipment to the patients and assisted one patient down a flight of stairs. Between the three calls and after the last call, Engine 37 returned to the gym and the crew continued playing competitive basketball, resting about 10 minutes between games and rehydrating.

At about 1315 hours, Engine 37 left the gym to get lunch. Stopping at a local restaurant, crew members entered and ordered their food. After the Engineer placed his order, he walked outside to call his wife. After a few minutes, a customer entered the restaurant and advised a crew member that "she needed help outside; a person was down on the sidewalk." As the crew proceeded to the door, she turned and stated that it was "one of them." The crew continued outside and found the Engineer

collapsed, unresponsive, with agonal breathing and no pulse. It first appeared the Engineer was having a seizure. Dispatch was notified at 1343 hours and an ambulance was dispatched.

Crew members (Fire Fighter-Paramedics) began CPR, retrieved their medical equipment (oxygen and intravenous equipment and a cardiac monitor), and began advanced life support. CPR continued for two minutes as cardiac monitor leads were attached to the Engineer. The monitor revealed ventricular fibrillation, and two shocks were delivered. The Engineer was intubated (breathing tube inserted into the trachea) with placement confirmed by end-tidal carbon dioxide testing and auscultation. An intravenous line was placed and cardiac resuscitation medications were administered. Rescue 31 arrived on the scene at 1348 hours and additional advanced life support measures, including three additional shocks, were performed. Rescue 31 departed the scene at 1354 hours en route to the hospital. Two additional shocks were delivered en route with no positive change in the Engineer's heart rhythm, which had reverted to pulseless electrical activity. Rescue 31 arrived at the hospital's Emergency Department 7 minutes later (1401 hours).

Inside the Emergency Department, advanced life support treatment continued. Despite these resuscitation measures, the Engineer's condition did not improve. At 1427 hours, the attending physician pronounced the Engineer dead, and resuscitation measures were discontinued.

Medical Findings. The death certificate and autopsy (completed by the Medical Examiner) listed "coronary artery heart disease" as the cause of death. Pertinent findings from the autopsy, performed on June 7, 2007, included:

- Cardiomegaly (heart weighed 650 grams [g]; normal weight is <400 g) [Siegel 1997a]
- Atherosclerotic coronary artery disease (CAD)
- Severe (95%) focal narrowing of the right coronary artery
- Moderate (80%) focal narrowing of the left anterior descending coronary artery
- No evidence of a thrombus (blood clot) in the coronary arteries
- Focal fibrosis of the posterior and septal walls of the left ventricle consistent with a remote
- (old) myocardial infarction (heart attack)
- Left ventricular hypertrophy
- Left ventricular wall thickened (2.0 centimeters [cm])
  - Normal thickness at autopsy is 0.76-0.88 cm [Colucci and Braunwald 1997]
  - Normal thickness by echocardiogram is 0.6-1.1 cm [Armstrong and Feigenbaum 2001]
- Interventricular septum thickened (1.9 cm)
  - Normal thickness by autopsy is 0.76-0.88 cm [Colucci and Braunwald 1997]
  - Normal thickness by echocardiogram is 0.6-1.1 cm [Armstrong and Feigenbaum 2001]
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative drug and alcohol tests

Microscopic examination of the heart's left ventricle revealed "marked interstitial and perivascular fibrosis, with numerous capillaries, and some scattered lymphocytes."

These findings were consistent with a remote heart attack. Microscopic examination of two sections of the coronary arteries revealed severe (95 – 100%) atherosclerosis occlusive disease with calcification, revascularization, and fibromuscular hyperplasia.

The Engineer was 73" tall and weighed 232 pounds, giving him a body mass index (BMI) of 30.6. A BMI >30.0 (kilograms per meters squared [kg/m^2]) is considered obese [National Heart, Lung and Blood Institute 2005]. This Fire Department determines the body fat of each fire fighter by a skinfold test during their annual medical evaluation. Many consider the skinfold test a more accurate method of determining percent body fat than BMI [Jackson et al. 2004, Nooyens et al. 2007]. The Engineer's body fat was <25% (e.g., not obese).

The Engineer had a history of hypertension since 1992 and was prescribed an antihypertensive medication. However, his blood pressure remained elevated (140/100 mmHg; 167/95 mmHg) at several Fire Department medical evaluations (2001, 2002, and 2004). His blood cholesterol level had been elevated since 2000, and he was prescribed a low cholesterol diet, but he was not prescribed a cholesterol-lowering medication due to his total cholesterol/high density lipoprotein (HDL) ratio being in the normal range (<5.0).

The Engineer was diagnosed with an intra-abdominal/aortic lymphoma in 1990 and was treated with surgery and chemotherapy. He was diagnosed with testicular cancer in 1999 and was treated with surgery and radiation. In 2005, the Engineer was diagnosed with prostate cancer and was treated with surgery.

At his last Fire Department medical evaluation in 2004, a treadmill fitness test was conducted using the Davis protocol. Prior to the start of the exercise stress test the Engineer's blood pressure was slightly elevated at 138/92 mmHg. The Engineer exercised for 4 minutes, 9 seconds (9.7 metabolic equivalents [METS]) reaching a peak heart rate of 152 beats per minute (85% of his maximum). His blood pressure rose minimally during the treadmill test (142/90 mmHg), but rose to 210/90 mmHg during the first minute of recovery before returning to baseline. No ischemic ST-T wave changes were seen during exercise. The Engineer's pattern of rising blood pressure during the recovery phases of the exercise stress test was also seen in 2001 and 2002, where his blood pressure rose to 240/110 mmHg during the third minute of recovery.

A heart murmur was identified during the Engineer's Fire Department medical evaluation in 2001, and a second murmur identified in 2002; the Engineer was advised to follow-up with a cardiologist. However, no follow-up occurred. At a return-to-duty medical evaluation in 2005, no murmurs were identified. At autopsy, the Engineer had no heart valve abnormalities.
The Engineer missed his annual medical evaluations in 2005 and 2006 due to vacations and being reassigned during the Fire Department district restructuring. According to his family and crew members, the Engineer had no complaints of chest pains, unusual shortness of breath on exertion, or any other heart-related illness.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this career Fire Department consisted of 1,628 uniformed personnel, and served a population of 1,575,000 in a 516-square-mile area. It had 53 fire stations where fire fighters work 24-hour shifts (starting at 0800 hours) according to the following tour: 24 hrs-on, 48 hrs-off, with a Kelly Day. In 2006, the Fire Department responded to 151,612 calls (128,726 medical calls, 16,327 fire calls, 5,579 miscellaneous calls, and 980 special operation calls). There were 285,659 unit responses and 56,689 rescue transports. Engine 37, an advanced life support engine, responded to 2732 calls, averaging 7.48 calls per shift. Engines are staffed with 4 personnel; ladder trucks with 5 personnel.

Employment and Training. The Fire Department requires the following of all fire fighter applicants:

- be at least 18 years of age
- have the ability to read and comprehend written material at the grade 14 level
- possess the mental, physical, and medical health to adequately perform the duties of a fire fighter
- have or be able to obtain a valid State Driver's license and have maintained a good driving
- record (fewer than 8 points the previous years)
- use no tobacco of any kind
- complete an application
- pass a written general knowledge test
- pass a candidate physical ability test (CPAT) [IAFF, IAFC 1999]

The successful applicant completing the CPAT is placed on an eligibility list. The applicant must then pass an oral board interview, a background check, two pre-placement medical evaluations, and a drug screen. Applicants must provide proof of valid Emergency Medical Technician (EMT) certification 2 weeks prior to employment. Applicants living outside the county must meet residency requirements within 24 months of employment.

New hires are placed into the 12-week Recruit Academy. The successful graduate is trained to the NFPA Fire Fighter I (FFI) and Fire Fighter II (FFII) levels, and is placed in the field as a probationary fire fighter for 9 months. The new fire fighter continues training until the end of the probationary period. Fire fighters are then assigned to emergency medical transportation duty for 200 shifts. Following this period, fire fighters are assigned to fire companies. State fire fighter certification is voluntary for all fire fighters (FFI and FFII). There is no annual recertification requirement. The Engineer was certified as an FFII, EMT-Paramedic, Engineer, and in Hazardous Materials Awareness. He had 16 years of firefighting experience.

Pre-placement Medical Evaluation. A pre-placement medical evaluation is required for all new hires, regardless of age. Components of this evaluation include:

- A complete medical history
- Height, weight, and vital signs
- Physical examination
- Blood tests: complete blood count (CBC), blood chemical 18 (chem. 18) panel, and lipid profiles
- Urine dipstick test
- Urinalysis
- Exercise treadmill test

- Vision testing
- Audiogram

This evaluation is performed by the Fire Department physician, who makes a decision regarding medical clearance for firefighting duties based on recommended standards in NFPA 1582 [NFPA 2007]. The Fire Department is notified of any condition requiring modification or restriction of duties. Results of the medical evaluation are kept confidential by the physician, and only the clearance status is reported to the Fire Department.

Annual Medical Evaluations. Annual medical evaluations are required for all fire fighters and are scheduled with their assigned fire company. Components of this evaluation are essentially the same as those of the candidate pre-placement medical evaluation with the following exceptions. Treadmill fitness tests are given every 3 years for members 30 years and younger, every 2 years for members 30-39 years old, and every year for members 40 and older. In years that a treadmill stress EKG is not performed, aerobic capacity is determined by another form of aerobic testing. Chest x-rays are conducted every other year. Medical clearance for SCBA use is required for all fire fighters.

If a member misses his/her scheduled annual medical evaluation, the member must reschedule a medical evaluation within 30 days. If the member misses his/her second appointment, the Health Center will reschedule the appointment. If the member misses the second appointment, the member is considered not medically cleared for duty and directed to the Health Center for the first available appointment by his/her District Commander or Battalion Chief. An employee may waive the annual medical evaluation only if he/she has the medical evaluation performed by a licensed physician. If the member chooses to see his/her private physician, an appointment must be made with the private physician within 30 days of the member's scheduled Health Center evaluation. The required results are sent to the Health Center to be reviewed by the Fire Department physician. Despite these policies, the Engineer missed both his 2005 and 2006 medical evaluations.

If a fire fighter is injured at work, a return-to-duty medical clearance is required from the Fire Department physician, who makes the final determination for return-to-duty. If an off-duty injury or illness prevents a fire fighter from performing his or her duty for three shifts, a return-to-duty clearance is required from the fire fighter's primary care physician, which is provided to the Fire Department physician, who makes the final return-to-duty medical determination. If the fire fighter is off for 10 shifts, a return-to-duty clearance is required from the Fire Department physician, who makes the final return-to-duty medical determination.

Health/Wellness Programs. Participation in the Fire Department's physical fitness program is mandatory. This consists of using the strength and aerobic equipment available in the fire stations or playing strenuous basketball each shift. An annual physical ability test is not required.

DISCUSSION

The Engineer's sudden cardiac death was probably related to any or all of the following:

1) Atherosclerotic CAD
2) Left ventricular hypertrophy

3) Cardiomegaly
4) Physical exertion associated with playing basketball and responding to three emergency calls

In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2005]. Risk factors for its development include age over 45, male gender, family history of CAD, high blood pressure, high blood cholesterol, obesity, physical inactivity, and diabetes [American Heart Association (AHA) 1998; Jackson et al. 2001]. The Engineer had three of these risk factors (age over 45, male gender, and hypertension).

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2005]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. 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.

Diagnosing a heart attack requires any of the following: characteristic EKG changes elevated cardiac enzymes, or coronary artery thrombus. In the Engineer's case, he never regained a heart rhythm on which an EKG could reveal characteristic changes, cardiac enzymes need at least 4 hours post-heart attack to become elevated (he died within 1 hour), and no thrombus was found at autopsy [AHA 2006]. However, not all heart attacks have an associated coronary artery thrombus. Given the autopsy findings of severe focal CAD and focal fibrosis of the left ventricle walls consistent with a remote (old) heart attack, it is possible the Engineer suffered another "silent" or asymptomatic heart attack. In up to 20% of individuals, the first evidence of CAD may be myocardial infarction or sudden death [Libby 2005; Thaulow et al. 1993].

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks [Willich et al. 1993; Mittleman et al. 1993; Siscovick et al. 1984; Tofler et al. 1992]. The Engineer had played competitive basketball for approximately 3 hours. This activity expended about 8 METs, which is considered heavy physical activity [American Industrial Hygiene Association Journal 1971; Ainsworth 2003; Ainsworth et al. 1993]. He had also responded to three emergency calls, which has been shown to increase the heart rate of fire fighters, and to trigger cardiac events in fire fighters [Barnard 1975, Kales 2003, Kales 2007, Hales 2007]. Given the Engineer's underlying CAD, the physical stress of playing competitive basketball and responding to three calls could have triggered a heart attack, causing his subsequent cardiac arrest and death.

Left Ventricular Hypertrophy and Cardiomegaly. On autopsy, the Engineer had an enlarged heart (cardiomegaly) and left ventricular hypertrophy. The Engineer's left ventricular hypertrophy was probably due to his longstanding poorly controlled hypertension and his underlying CAD with associated ischemic heart disease. Both left ventricular hypertrophy and cardiomegaly are associated with an increased risk of sudden cardiac death [Siegel 1997a; Siegel 1997b; Bigger 1994].

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac death or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582 [NFPA 2007]. NFPA recommends annual medical evaluations include an EKG. Had the Engineer not missed his annual Fire Department medical evaluations in 2005 and 2006, perhaps his left ventricular hypertrophy would have been detected. This may have led to further medical evaluation (i.e., an echocardiogram) and treatment.

The Engineer had an EKG conducted in 2005 for his cancer surgery. This pre-op EKG showed newly inverted T waves in the inferior leads; a finding suggestive, but not diagnostic, for ischemic heart disease. Neither the hospital physician clearing the Engineer for surgery nor the Fire Department physician had access to both the old and new EKGs for comparison. If this change in EKG (newly inverted T waves) had been detected, perhaps this would have led to further medical evaluation (i.e., a maximum exercise stress test) and treatment.

In addition to screening for risk factors for CAD, NFPA 1582 recommends conducting stress tests on members over the age of 45 with two or more CAD risk factors (hypercholesterolemia, hypertension, smoking, diabetes mellitus, or family history or premature CAD) [NFPA 2007]. These recommendations are similar to those of the American College of Cardiology (ACC)/ American Heart Association (AHA) [Gibbons et al. 2002]. The Engineer had two current risk factors for CAD (hypercholesterolemia and hypertension), and, per Fire Department protocols, had exercise stress tests in 2000, 2001, and 2004. Although the Engineer had no ischemic changes on EKG, he did have an abnormal blood pressure response during recovery. It is unclear if the Engineer ever had further medical evaluations for this finding.

Finally, as mentioned earlier, the Engineer missed his 2005 and 2006 medical evaluation, including his EKG and exercise stress test. It is possible, had these medical evaluations and cardiac tests been performed, his underlying CAD could have been identified. If identified, he might have gone on to further evaluation and treatment, which may have prevented his sudden cardiac death at this time.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendation to prevent similar incidents.

Recommendation #1: Ensure annual medical evaluations that include EKGs and exercise stress tests are performed for fire fighters at risk for coronary artery disease.

This Fire Department follows NFPA 1582. It has policies in place to ensure that fire fighters do not "slip through the cracks" with regard to annual medical evaluations, but as this case demonstrates, implementation is not perfect. The NIOSH investigators do not have any additional policy suggestions to prevent another occurrence other than persistent and meticulous follow-up by the medical clinic staff and supervisors. Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 [NFPA 2007] and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) *Fire Service Joint Labor Management Wellness/Fitness Initiative* [IAFF, IAFC 1999]. However, the Fire Department is not legally required to follow this standard or this initiative.

The following recommendation is made to enhance safety and health. It did not contribute to the Engineer's death.

Recommendation #2: Eliminate or reduce the frequency of periodic chest x-rays in asymptomatic fire fighters, unless clinically indicated.

According to NFPA 1582, "chest x-rays shall include an initial baseline and shall be repeated every 5 years or as medically indicated" [NFPA 2007]. In addition, chest x-rays are not recommended by the OSHA Hazmat Standard, unless clinically indicated (e.g., respiratory symptoms) [CFR[1] 2002, NIOSH 1985]. Chest x-rays are currently being conducted every other year during the FD's annual medical evaluation. Conducting chest x-rays this frequently exposes members to unnecessary radiation and is an unnecessary expense.

[1]*Code of Federal Regulations*. See CFR in references.

REFERENCES

AHA [1998]. AHA scientific position, risk factors for coronary artery disease. Dallas, TX: American Heart Association.

AHA [2006]. Blood tests for rapid detection of heart attacks. Dallas, TX: American Heart Association. [http://www.americanheart.org/presenter.jhtml?identifier=4477]. Date accessed: July 2006.

American Industrial Hygiene Association Journal [1971]. Ergonomics guide to assessment of metabolic and cardiac costs of physical work. Am Ind Hyg Assoc J 560-564.

Ainsworth BE [2003]. The compendium of physical activities. President's Council on Physical Fitness and Sports: 4(2). Washington, DC.

Ainsworth BE, Haskell WL, Leon AS, Jacobs DR Jr, Montoye HJ, Sallis JF, Paffenbarger RS [1993]. Compendium of physical activities: classification of energy costs of human physical activities. Med Sci Sports Exerc 25(1):71-80.

Armstrong WF, Feigenbaum H [2001]. Echocardiography. In: Braunwald E, Zipes DP, Libby P, eds. Heart disease: a text of cardiovascular medicine. 6th ed. Vol. 1. Philadelphia, PA: W.B. Saunders Company, p. 167.

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

Bigger, JT Jr. [1994]. Role of left ventricular ejection fraction. In: Akhtar M, Myerburg RJ, and Ruskin JN, eds. Sudden cardiac death. Philadelphia, PA: Williams & Wilkins, p. 191.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

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

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.

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: a report of the American College of Cardiology / American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing). [http://content.onlinejacc.org/cgi/content/short/40/8/1531].

Hales TR, Jackson JS, Baldwin T [2007]. NIOSH alert. preventing fire fighter fatalities due to heart attacks and other sudden cardiovascular events. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health Publication No. 2007-133.

IAFF, IAFC [1999]. The fire service joint labor management wellness/fitness initiative, candidate physical ability test. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs.

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

Jackson AS, Pollock ML [2004]. Generalized equations for predicting body density of men. 1978. Br J Nutr 91(1):161-168.

Jackson E, Skerrett PJ, Ridker PM [2001]. Epidemiology of arterial thrombosis. In: Coleman RW, Hirsh J, Marder VIJ et al., eds. Homeostasis and thrombosis: basic principles and clinical practice. 4th ed. Philadelphia, PA: Lippincott Williams and Wilkins.

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: February 15, 2007.

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

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

Meyerburg RJ, Castellanos A [2005]. Cardiovascular collapse, cardiac arrest, and sudden cardiac death. In: Kasper DL, Braunwald E, Fauci AS, Hauser SL, Longo DL, Jameson JL, eds. Harrison's principles of internal medicine. 16th ed. New York: McGraw-Hill, pp. 1618-1624.

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 329:1677-1683.

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

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/85-115.html]. Date accessed: September 2006.

National Heart, Lung, and Blood Institute [2005]. Obesity education initiative. [http://www.nhlbisupport.com/bmi/bmicalc.htm]. Date accessed: August 2007.

Nooyens ACJ, Koppes LLJ, Visscher TLS, Twisk JWR, Kemper HCG, Schuit AJ, van Mechelen W, Seidell JC [2007]. Adolescent skinfold thickness is a better predictor of high body fatness in adults than is body mass index: the Amsterdam Growth and Health Longitudinal Study. Am J Clin Nutr 85:1533-1539.

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

Siegel RJ [1997a]. Cardiomegaly. In: Bloom S, ed. Diagnostic criteria for cardiovascular pathology acquired diseases. Philadelphia, PA: Lippencott-Raven, p. 12.

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

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

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

Tofler GH, Muller JE, Stone PH, Forman S, Solomon RE, Knatterud GL, Braunwald E [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the Thrombolysis in Myocardial Infarction Phase II (TIMI II) Study Group. J Am Coll Cardiol 20:1049-1055.

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 329:1684-1690.

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