Wildland Fire Fighter Trainee Suffers Sudden Cardiac Death During Physical Fitness Exercise – California

Executive Summary

In 2011, a 54-year-old State inmate was accepted into the State’s “Conservation Camps” program which trains inmates for wildland fire suppression. On January 4, 2012, the trainee was participating in a physical fitness exercise which involved hiking in moderately steep terrain while wearing wildland personal protective equipment (PPE) and carrying handtools. The PPE and the tools weighed approximately 18 pounds. As the Trainee completed the exercise, the crew leader determined he needed medical attention and called for an ambulance. While awaiting an ambulance, the Trainee’s condition deteriorated and he became unresponsive. Cardiopulmonary resuscitation (CPR) was begun and 15 minutes later an automated external defibrillator (AED) from the responding engine arrived and advised no shock. Approximately 3 minutes later, the ambulance with paramedics arrived and provided advanced life support (ALS). Despite CPR and ALS in the ambulance and in the local hospital’s emergency department (ED), the Trainee died.

The autopsy report listed “acute myocardial infarction due to atherosclerotic coronary artery disease” as the cause of death. Given the Trainee’s underlying cardiovascular disease, NIOSH investigators concluded that the physical stress of physical fitness training probably triggered his sudden cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues and to prevent future similar events.

Provide preplacement and annual medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, and NFPA 1051, Standard for Wildland Fire Fighter Professional Qualifications.

Make basic life support equipment, including an AED, readily available during strenuous training exercises.

Provide fire fighters with medical clearance to wear a respirator as part of the Fire Department’s medical evaluation program.

Provide annual respirator fit testing for fire fighters who wear respirators.

Introduction & Methods

On January 4, 2012, a 54-year-old male wildland fire fighter trainee collapsed during physical fitness training and died. NIOSH contacted the affected agency (State Department of Corrections) on January 12, 2012, to gather information, and again on February 15, 2012, to initiate the investigation. On March 1, 2012, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.
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The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH “Fire Fighter Fatality Investigation and Prevention Program” which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency’s reports do not name the victim, the fire department or those interviewed. The NIOSH report’s summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency's recommendations and is not intended to be definitive for purposes of determining any claim or benefit. For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).
Wildland Fire Fighter Trainee Suffers Sudden Cardiac Death During Physical Fitness Exercise – California

Introduction & Methods (cont.)

During the investigation, NIOSH personnel inter-
viewed the following people:

- Fire Chief
- Correctional Officers Crew members

NIOSH personnel reviewed the following docu-
ments:

- FD standard operating procedures
- Facility incident reports
- Emergency medical service (ambulance) report
- Hospital’s ED report
- Autopsy
- Correctional facility physician records

Investigative Results

Investigative Results (cont.)

approximately 10 pounds), and canteens. The crew
also carried hand tools such as an axe or forestry
rake which weighed about 5–8 pounds.

Throughout the hike, the Trainee did not report
any symptoms or exhibit any signs of a medical
problem. As the Trainee reached the top of the hill
(approximately 1540 hours), he became short of
breath and began crawling on his hands and knees
near the finish point. The Captain observed the
Trainee, determined he needed medical attention,
and tried unsuccessfully (due to an insufficient
radio signal) to contact the local emergency com-
mand center. He successfully reached the com-
mand center by cell phone at 1544 hours and re-
quested an ambulance. While the Captain was on
the phone with the command center, the Trainee
suddenly became unresponsive with no pulse and
no respirations. Crew members began CPR.

The dispatch/command center notified the ambu-
lance service at 1545 hours, and Medic 52 re-
plied at 1548 hours. Meanwhile, Engine 5188
from the correctional facility’s fire department was
dispatched via mutual aid. Engine 5188 arrived at
the scene at 1559 hours to find the Trainee unre-
sponsive, with no pulse or respirations, and with
CPR in progress. An AED was attached to the
Trainee, and no shock was advised. An oropharyn-
geal airway was inserted and oxygen was adminis-
tered via bag-valve-mask.

Medic 52 arrived at 1602 hours and began ALS in-
cluding intubation and intravenous line placement.
Tube placement was verified by capnography
[Neumar et al. 2010]. The Trainee was placed into
the ambulance which departed the scene en route
to the hospital’s ED at 1619 hours.

The morning of January 4, 2012 was spent on
classroom and orientation training. At approxi-
mately 1520 hours, the Trainee, other trainees, and
the State forestry fire captain began the physical
fitness hike. All wore full wildland PPE including
Nomex® pants, Nomex® top, helmet, gloves, fire
pack with integrated hydration reservoir (weighing

Incident. On January 4, 2012, the Trainee began
his first day of wildland fire fighter training. Fif-
teen trainees participated in the training which
included hiking in terrain with a 14-degree slope
(511 feet of elevation in 0.7 miles). The train-
ing program was one of 42 throughout California
training State inmates to become wildland fire
fighters. It is administered by the State’s Depart-
ment of Corrections (the Agency) and the State’s
Division of Forestry. In addition to fighting wild-
land fires, trained personnel respond to other
emergencies such as floods and earthquakes, and
assist with conservation projects. Approximately
4,000 inmates participate in the program on ap-
proximately 200 fire crews.

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to the hospital’s ED at 1619 hours.
Medic 52 arrived at the ED at 1630 hours, approximately 45 minutes after the Trainee’s collapse. Inside the ED, resuscitation efforts continued until 1642 hours when the attending physician pronounced the Trainee dead.

**Medical Findings.** The autopsy report, completed by the county pathologist, listed “acute myocardial infarction due to atherosclerotic coronary artery disease” as the cause of death. Findings from the autopsy are listed in Appendix A.

The Trainee was 70 inches tall and weighed 199 pounds, giving him a body mass index of 28.6 kilograms per meters squared. A BMI of 25.0 – 29.9 kg/m2 is considered overweight [CDC 2011]. The Trainee’s risk factors for coronary artery disease included hypertension (high blood pressure) diagnosed prior to 2010 and hypercholesterolemia (high blood cholesterol) diagnosed in 2011. He was prescribed diet modification, exercise, and medications. Although a blood pressure-lowering medication and a cholesterol-lowering medication were prescribed, the Trainee did not fill the prescriptions. The Trainee never complained about cardiac symptoms and participated in the Agency’s 4-week wellness/fitness program (described below). During his preplacement medical evaluation in September 2011, the Trainee was cleared for vigorous firefighting duties.

At the time of the NIOSH investigation, the correctional facility maintained 12 structural fire fighters (1 fire station) and 108 wildland fire fighters; all were inmates. Additional trained inmates staffed a mobile kitchen which deployed to emergency incidents. The structural fire fighters provide fire and emergency medical response to the correctional facility which includes three structures with 1.2 million square feet housing approximately 5,700 inmates. The 108 wildland fire fighters service a 6-square mile area.

**Membership and Training.** The State Agency requires new inmate fire fighter applicants to pass a medical evaluation (discussed below), a candidate physical ability test (discussed below), and an interview. Structural fire fighter trainees are assigned to the FD to begin First Responder and Fire Fighter 1 and 2 training provided the inmate is not schedule for release prior to completing these programs.

**Medical Evaluations.** The Agency requires preplacement medical evaluations for all fire fighter applicants and annual evaluations for members. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Blood tests: complete blood count, lipid panel

The evaluations are performed by an Agency physician. Once an evaluation is completed, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD. It is unclear if this medical clearance also clears the applicant...
Description of the Facility (cont.)

to wear a respirator. An annual SCBA facepiece fit test is not required.

Fitness Program and Physical Ability Test. All fire fighter candidates and members must participate in the 4-week physical fitness program. Exercise equipment is provided in the fire station and training areas. At the end of the program, candidates must pass two physical ability tests, including a gym test (Appendix B), and a hill climb. The hill climbing involved climbing a 0.7-mile hill with a 14-degree slope.

The Trainee had participated in the 4-week physical fitness program by running, circuit training (squats, burpees, push-ups, mountain climbers, chair dips, toe-ups, jump rope, jumping jacks, Harvard steps, and plyometrics), obstacle jump, abdominal workout, exercise band, medicine ball, and ankle weights. He also passed the gym portion of his physical fitness test. He was training for the hill climb when he suffered his sudden cardiac death. He had no prior fire fighting experience.

Other Medical Evaluations. Members injured on duty are evaluated by the Agency physician. The physician determines the functional capacity level (vigorous duty, full duty, limited duty, totally disabled) and forwards their medical clearance opinion to the Agency. Members who are ill and miss two or more shifts must provide a medical clearance statement from the Agency physician.

Discussion

Atherosclerotic Coronary Heart Disease (CHD). 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 [NHLBI 2011; AHA 2012a]. The Trainee had four CHD risk factors (age older than 45, male gender, high blood pressure, and high blood cholesterol).

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 was not performed because the Trainee had no heart beat, cardiac enzymes were not tested, and no coronary artery thrombus was identified at autopsy. However, heart attacks can occur without evidence of a coronary thrombus [Davies 1992; Farb et al. 1995]. Thus, although not confirmed, a heart attack was probably responsible for the Trainee’s sudden death and was listed as the cause of death on the death certificate and autopsy report.
A Summary of a NIOSH fire fighter fatality investigation

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Discussion (cont.)

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks in firefighters 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 Trainee had performed physical fitness training by hiking up a 14% slope, 511 feet of elevation within 0.7 miles with about 18 pounds of gear. This activity expended about 8 metabolic equivalents (METs), which is considered moderate physical activity [AIHA 1971; Ainsworth et al. 2011]. NIOSH investigators conclude that the Trainee’s sudden cardiac death was probably an acute myocardial infarction triggered by his physical activity in conjunction with his underlying CHD.

Primary Arrhythmia. A primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) could have also been responsible for the Trainee’s sudden cardiac death. Risk factors for arrhythmias include heart disease, heart attack, dietary supplements, smoking, alcohol, drug abuse, medications, diabetes, and hyperthyroidism [Mayo Clinic 2011; AHA 2012b]. Although the Trainee did not have known heart disease prior to his death, his autopsy confirmed moderate CHD and cardiomegaly (discussed below). These conditions increase the risk for a primary arrhythmia and sudden cardiac death [Levy 1990].

Occupational Medical Standards for Wildland Fire Fighters. NFPA 1051, Standard for Wildland Fire Fighter Professional Qualifications, sets forth the requirements to become a wildland fire fighter including physical fitness and medical considerations. For medical clearance, NFPA 1051 refers to NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a; NFPA 2007b].

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 2007b]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Trainee did not have any known medical conditions that would have required restrictions. However, he did have CHD risk factors, which in consideration of the Trainee’s age, should have triggered an exercise stress test [NFPA 2007b] (see next section).

Exercise Stress Tests. Guidance regarding testing asymptomatic individuals without known heart disease with exercise stress tests is varied. The following paragraphs summarize the positions of widely recognized organizations on this topic.

National Fire Protection Association (NFPA) 1582, a voluntary industry standard, recommends an exercise stress test be performed “as clinically indicated by history or symptoms” and refers the reader to Appendix A [NFPA 2007b]. 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
Discussion (cont.)

following conditions:
● abnormal screening submaximal tests
● cardiac symptoms
● known coronary artery disease
● two or more risk factors for coronary artery disease (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 coronary artery disease (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 that the evidence to conduct stress tests in asymptomatic individuals 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 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 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 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, the USPSTF recommends 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 the Trainee’s age and CHD risk profile, the NFPA, the ACC/AHA, and the DOT would have recommended a symptom-limiting exercise stress test.
Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues and to prevent future similar events.

**Recommendation #1: Provide preplacement and annual medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, and NFPA 1051, Standard for Wildland Fire Fighter Professional Qualifications.**

Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 [NFPA 2007b]. While the Agency conducts preplacement and annual medical evaluations, these evaluations do not include exercise stress tests for candidates/members at risk for CHD. NIOSH investigators recommend the Agency conduct exercise stress tests for fire fighters at increased risk for coronary heart disease based on the NFPA and the ACC/AHA guidelines [Gibbons et al. 2002; NFPA 2007b]. Although NIOSH recommends following these guidelines, the Agency is not legally required to follow them.

**Recommendation #2: Make basic life support equipment, including an AED, readily available during strenuous training exercises.**

Preservation of human life is the primary responsibility of the fire department during fires and other emergencies. Most of the sudden cardiac deaths in the United States result from ventricular fibrillation. The chain of survival from cardiac arrest includes: (1) immediate recognition of cardiac arrest and activation of the emergency response system, (2) early CPR with an emphasis on chest compressions, (3) rapid defibrillation, (4) effective advanced life support, and (5) integrated post-cardiac arrest care [AHA 2011]. Rapid defibrillation using AEDs has increased the cardiac arrest survival rate from 6.7% (CPR performed only) to 34% [Sasson et al. 2010; Weisfeldt et al. 2011]. When defibrillation is provided within 3–5 minutes, the survival rate is as high as 74% [Link et al. 2010]. The FD engine had an AED, but it was 15 minutes away. The Trainee’s chances of surviving cardiac arrest would have increased if an AED was readily available and an AED-trained responder was nearby [Marenco et al. 2001; Koster 2002].

**Recommendation #3: Provide fire fighters with medical clearance to wear a respirator as part of the Fire Department’s medical evaluation program.**

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR 1910.134]. These clearance evaluations are required for private industry employees and public employees in states operating OSHA-approved state plans. California operates an OSHA-approved state plan; therefore the Agency is required to ensure all structural fire fighters have been medically cleared to wear a respirator.

**Recommendation #4: Provide annual respirator fit testing for fire fighters who wear respirators.**

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires that, before an employee may be required to use any respirator with a negative
Wildland Fire Fighter Trainee Suffers Sudden Cardiac Death During Physical Fitness Exercise – California

Recommendations (cont.)

or positive pressure tight-fitting facepiece, the employee must be fit tested with the same make, model, style, and size of respirator that will be used [29 CFR 1910.134]. Because California operates an OSHA-approved state plan, the Agency is required to ensure all fire fighters have been fit tested to wear an SCBA or tight fitting respirator.

References


References (cont.)


Wildland Fire Fighter Trainee Suffers Sudden Cardiac Death During Physical Fitness Exercise – California

References (cont.)


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).

Autopsy Findings
- Coronary artery atherosclerosis
  - Moderate to severe (70%) focal narrowing of the left anterior descending coronary artery
  - Cardiomegaly (enlarged heart; heart weighed 500 grams [g]; predicted normal weight is 371 g [ranges between 281 g and 489 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
- Normal cardiac valves
- No evidence of a coronary artery thrombus (blood clot)
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative

Reference
Appendix B

Physical Ability (Gym) Test

- Set One includes push ups, chair dips, Ab crunches, and toe ups for 1 minute each
- Set Two includes side situps (1 minute each side), knee up crunches, push ups, and burpees (squat thrust) for 2 minutes each
- Set Three includes flutter kick, push ups, mountain climbers, and bench crunches for 2.5 minutes each
- Harvard steps (the subject steps up and down on a platform at a height of about 45 cm. at a rate of 30 steps per minute) for 1 minute each leg
- Harvard steps for 2 minutes each leg
- Harvard steps for 3 minutes each leg