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NIOSH
Fire Fighter Fatality Investigation and Prevention Program

# Death in the line of duty...

*A summary of a NIOSH fire fighter fatality investigation* *September 2008*

# Fire Fighter Trainee Suffers Sudden Cardiac Death During Strenuous Training Drill – Georgia

## SUMMARY

On February 21, 2008, a 48-year-old male volunteer Fire Fighter Trainee participated in a State Fire Academy training activity known as the maze drill. The maze drill simulates a lost fire fighter crawling through restricted passageways. As required by one component of the drill, the Trainee exhausted his air bottle, unhooked his facepiece regulator, and exited the maze. Immediately after exiting the maze, he collapsed. Emergency medical technicians (EMTs) on the scene began medical treatment and an ambulance was dispatched. Advanced life support treatment was provided and the Trainee was transported to the hospital's Emergency Department, where he was treated and transferred to a regional hospital. He died the next day. The death certificate, completed by the attending physician, listed "cardiorespiratory arrest" due to "cardiogenic shock" as the cause of death. The autopsy, completed by the Medical Examiner, listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. The NIOSH investigator concluded that the physical stress of performing the maze drill coupled with the Trainee's underlying coronary artery disease (CAD), probably triggered his sudden cardiac death.

The NIOSH investigator offers the following recommendations to prevent similar incidents and to address general safety and health issues.

- Provide mandatory pre-placement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard

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 Web site at

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on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

- Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.
- Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural firefighting.
- Phase-in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.
- Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.

## INTRODUCTION & METHODS

On February 22, 2008, a 48-year-old male volunteer Fire Fighter Trainee died after strenuous activities associated with a maze drill. NIOSH was notified of this fatality on February 25, 2008 by the United States Fire Administration. NIOSH contacted the affected Fire Department on February 26, 2008 to obtain further information, and on March 3, 2008 to initiate the investigation. On March 10, 2008, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Georgia to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Deputy Fire Chief
- Director of the State Fire Academy
- Ambulance service personnel
- Fire Fighter's spouse

NIOSH personnel reviewed the following documents:

- Fire Academy incident reports
- Fire Department 2007 annual response report
- Ambulance service emergency medical report
- Local hospital Emergency Department record
- Regional hospital in-patient report
- Autopsy report
- Primary care physician records
- Military medical records

## RESULTS OF INVESTIGATION

***Incident.*** The Trainee was enrolled in an 8-day course (the Basic Firefighter Module 1 with Live Fire) at the Georgia Fire Academy. The class began on Sunday, February 17, 2008, at 0700 hours. The class included 27 students, 2 staff members, and 4 contract adjunct instructors who were also trained as EMTs.

***The State "Basic Fire Fighter Module One With Live Fire" Course***. One component of this course is the maze drill, which consists of the following elements:

- disoriented fire fighter
- skip breathing/emergency by-pass procedures
- restricted passage with SCBA (reduced profile maneuver)
- retreat to safe haven evolutions.

The disoriented fire fighter portion of the course requires wearing full turnout gear with SCBA on-air. Each trainee has wax paper placed into their facepieces to reduce visibility. The trainee is taken into the maze room and placed beside a wall. The trainee crawls on his/her hands and knees, staying in contact with the wall, until they locate a hose line. The trainee then follows the hose line for 150-feet, until he/she is out of the building.

The skip breathing and emergency by-pass portions require use of an SCBA with 1000 pounds of air. The participant exhausts their air supply, turns the SCBA to bypass air, unhooks their facepiece regulator, and crawls out.

The restricted passage and reduced profile segment of the drill require the trainees to wear full turnout gear with their SCBA on-air. The trainee "sounds" wall studs with a pick-head axe and removes wall material to provide a 16-inch opening. The trainee then partially removes their SCBA and rotates the SCBA until it is under their arm along the rib cage. If this does not allow the trainee to crawl through the opening, the trainee is supposed to perform a full escape by removing their SCBA harness assembly and passing the SCBA through the opening. Contact with the SCBA must always be maintained by holding the shoulder straps and regulator assembly, while ensuring the facepiece is not pulled away. As soon as the trainee is through the restricted space, the trainee re-dons the harness.

In this case, the Trainee completed the strenuous training for the first 4 days with no complaints or problems. Day 5 of the training (February 21st) consisted of the maze drill, located on the 2nd floor of the training tower, in which the participants crawled through restricted passageways.

The Trainee was student #19 to enter the maze (beginning at 0918 hours) to complete the skip breathing portion. An instructor watched the Trainee's progress through the maze. He completed the maze in 8 minutes at 0936 hours.

As the Trainee exited the maze, he collapsed. Instructors, EMTs, and inmate fire fighters (program described below) began treatment immediately. Other staff members retrieved the automated external defibrillator (AED) and medical kit and called 911 (0938 hours). The Trainee was carried to the ground level, and assessment revealed a slow pulse, but he was not breathing. The AED advised no shock. Shortly thereafter, his pulse stopped and cardiopulmonary resuscitation (CPR) was begun.

The ambulance arrived at 0944 hours and paramedics found the Trainee to be in cardiac arrest with CPR in progress. He was placed into the ambulance where a cardiac monitor revealed asystole (no heart beat). He was intubated (breathing tube inserted into the trachea). Tube placement was confirmed with bilateral breath sounds, and end tidal carbon dioxide detector. An intravenous line was placed and cardiac resuscitation medications were administered. The ambulance departed the scene at 0950 hours en route to the hospital's Emergency Department. Advanced life support continued en route with no positive change in the Trainee's condition.

The ambulance arrived at the hospital at 0958 hours. Inside the Emergency Department, advanced life support treatment continued. Additional cardiac resuscitation medications were administered. At 1006 hours, the Trainee's heart rhythm changed to pulseless electrical activity. At 1008 hours, the rhythm changed to atrial fibrillation; at 1032 hours, it returned to pulseless electrical activity. The Trainee was placed on a ventilator and a pulse returned at 1036 hours. An electrocardiogram (EKG) revealed atrial fibrillation with rapid ventricular response, right bundle branch block, and premature ventricular contractions. Cardiac enzyme testing revealed elevated blood levels consistent with a myocardial infarction (heart attack): creatine phosphokinase (CPK) (462 international units per liter [IU/L] [normal is 38-174 IU/L]), creatine kinase-MB (CKMB) (49.1 nanograms per milliliter [ng/mL] [normal is 0.6-6.3 ng/mL]), and troponin I (6.56 ng/mL [normal is 0.03-0.50 ng/mL]). His blood pressure and overall condition stabilized somewhat and he was transferred to a regional hospital for advanced care at 1202 hours.

An echocardiogram was performed which showed a normal left ventricular ejection fraction (60%) and normal ventricle sizes. Subsequent testing at the regional hospital identified severe hypoxic brain injury due to lack of oxygen during the resuscitation efforts. The Trainee's condition did not improve and he was removed from life support the next day, February 22nd. He died at 1525 hours.

***Medical Findings.*** The death certificate, completed by the attending physician, listed "cardiorespiratory arrest" due to "cardiogenic shock" as the cause of death. The autopsy, completed by the Medical Examiner on February 23, 2008, listed "atherosclerotic and hypertensive cardiovascular disease" as the cause of death. Pertinent findings from the autopsy included:

- Cardiomegaly (enlarged heart)(heart weighed 550 grams [g]; normal weight is <400 g) [Siegel 1997a]
- Atherosclerotic CAD
  - Severe (90%) focal narrowing of the left anterior descending coronary artery
  - Moderate (75%) focal narrowing of the right coronary artery
  - Moderate (60%) focal narrowing of the circumflex coronary artery
  - No evidence of recent thrombus (blood clot in the coronary arteries)
- Acute ischemic infarction of muscle controlling one of the heart valves (posterior left ventricular papillary muscles) and patchy interstitial fibrosis of the posterior left ventricle consistent with a recent (24-48 hours duration) myocardial infarction (heart attack)
- Left ventricular hypertrophy (LVH)
  - Left ventricle and interventricular septum walls thickened (2.5 centimeters [cm];
    - normal at autopsy is 0.76-0.88 cm [Colucci and Braunwald 1997];
    - normal by echocardiographic measurement 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)
- Anoxic encephalopathy

The Trainee was 70 inches tall and weighed 176 pounds, giving him a "normal" body mass index (BMI) of 25.2 kilograms per meters squared (kg/m2) [CDC 2008]. The Trainee had a history of elevated blood lipids (elevated cholesterol, elevated low-density lipoprotein, and elevated cholesterol/high density lipoprotein ratio) since 2004. Diet modification did not result in improvement in the Fire Fighter's blood lipids, and no medications were prescribed.

According to his family, crew members, and roommate at the Fire Academy, the Trainee had no complaints of chest pains, unusual shortness of breath on exertion, or any other heart-related illness. The day before his collapse, the Trainee participated in physical fitness training (stretching exercises, a slow jog around the training tower pad and burn building pad, crawl from one hydrant to another hydrant 300-feet away, climb the tower up to the fourth floor and down, and walk to the attic simulator) for about 45 minutes. The rest of the day consisted of several training sessions spread between different work stations with a 15-minute rehabilitation period between each work station.

## DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this volunteer Fire Department consisted of 22 uniformed personnel, and served a population of 6,800 in a 776-square-mile area. It had three fire stations. In 2007, the Fire Department responded to 346 calls (109 fire alarms, 102 wildland fires, 47 hazardous material calls, 32 vehicle fires, and 56 other calls.

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

- be at least 18 years of age
- complete an application
- pass a drug screen and background check
- pass a Fire Department vote
- pass a physical ability test

The successful applicant is placed into a training program and is scheduled to attend the 8-day, 90-hour "Basic Firefighter Module One With Live Fire" course at the State Fire Academy. Volunteer fire fighters may take each training module separately. The fire fighter is placed on probation for 1 year and must complete the required training during this time. The State requires volunteer fire fighters to be registered with the State and to complete the "Basic Fire Fighter Module One With Live Fire" course. This is the prerequisite to being certified as a National Professional Qualification 1 Basic Fire Fighter (20-day, 187-hour course). The Trainee had 8 months of firefighting experience.

***State Department of Corrections Inmate Fire Fighter Program.*** The Department of Corrections operates 18 fire stations, with an additional three inmate-manned stations located in county correctional facilities. The program began in the early 1960's to augment local community fire departments. Inmate fire fighters respond to over 3,000 emergency calls each year in these communities. Statewide, over 200 inmates participate in the program. The "Inmate Fire Fighter Program" at the Georgia Public Safety Training Center (of which the Georgia Fire Academy is a part) is conducted by the Georgia Public Safety Training Center, not by the Department of Corrections. These inmates are trained to meet state Fire Fighter Standards and Training certification requirements and are trained in CPR and first aid. Each inmate fire fighter works from 0700 hours to 1600 hours Monday – Friday and is overseen by Fire Academy staff.

***Pre-placement and Annual Medical Evaluations.*** Pre-placement and annual medical evaluations, including medical clearance for respirator use, are not required by the Fire Department, however, hepatitis B vaccinations and titer tests, and tetanus vaccinations are provided free of charge by the County Health Department. SCBA fit testing is required annually for all fire fighters and each member is provided with their own facepiece.

If a fire fighter is injured on duty, a return-to-duty medical clearance is required from the Fire Department insurance-contracted 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, return-to-duty clearance is not required.

***Health/Wellness Programs.*** The Fire Department does not have a wellness or physical fitness program. Strength and aerobic equipment are not available in fire stations. An annual physical ability test is not required.

***State Fire Academy Medical Requirement.*** The State Fire Academy requires each trainee and a health care provider to complete a "Medical Affidavit" certifying that the trainee is in good physical condition as determined by a medical examination. The form is signed by a physician, physician's assistant, or a nurse (operating under a physician's authority). However, in this case, neither the Trainee nor the Trainee's Fire Department submitted a completed form to the Fire Academy.

## DISCUSSION

***Coronary Artery Disease and the Pathophysiology of Heart Attacks.*** In the United States, atherosclerotic CAD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. 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) 2008a]. The Trainee had three of these risk factors (age over 45, male gender, 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.

Diagnosing a heart attack requires any of the following: characteristic EKG changes, elevated blood cardiac enzymes, or coronary artery thrombus [AHA 2008b]. The Trainee's blood cardiac enzymes were diagnostic for an acute heart attack and the autopsy findings were consistent with an acute heart attack. Since the Trainee had performed exertional activities at the maze drill and did not complain of heart attack symptoms (e.g., chest pain/angina), it is possible he suffered a "silent" or asymptomatic heart attack. In up to 20% of individuals, the first evidence of CAD may be myocardial infarction or sudden death [Libby 2008; 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]. Heart attacks in fire fighters 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 crawled through the maze, exhausted his SCBA air, converted to bypass air, unhooked his SCBA, and crawled out. This activity expended about 10 metabolic equivalents (METs), which is considered heavy physical activity [American Industrial Hygiene Association Journal 1971; Gledhill and Jamnik 1992]. Given the Trainee's underlying CAD, the physical stress of performing exertional training activities could have triggered a heart attack, causing his subsequent cardiac arrest and death.

***Cardiomegaly/Left Ventricular Hypertrophy (LVH).*** On autopsy, the Trainee was found to have LVH and an enlarged heart. 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 high blood pressure (hypertension), a heart valve problem, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997b]. The Trainee did not have high blood pressure nor a heart valve problem, therefore his LVH was probably due to his CAD and chronic asymptomatic ischemia.

***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 2007a]. This voluntary industry standard specifies minimum medical requirements for candidates and current fire fighters.

***Screening Tests for Cardiac Disease – Stress Tests.*** In addition to screening for risk factors for CAD, NFPA 1582 recommends conducting diagnostic exercise stress tests on members over the age of 45 with two or more CAD risk factors (hypercholesterolemia, hypertension, smoking, diabetes mellitus, or family history of premature CAD) [NFPA 2007a]. These recommendations are similar to those of the American College of Cardiology (ACC)/AHA [Gibbons et al. 2002]. The Trainee had only one risk factor for CAD (high cholesterol), therefore, according to NFPA 1582, a symptom-limiting exercise stress test would not have been indicated.

## RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to prevent similar incidents and to address general safety and health issues.

***Recommendation #1: Provide mandatory pre-placement and annual medical evaluations to fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to determine their medical ability to perform***

***duties without presenting a significant risk to the safety and health of themselves or others.***

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2000]. However, the Fire Department is not legally required to follow this standard or this initiative. Applying this recommendation involves economic repercussions and may be particularly difficult for small, volunteer fire departments to implement. NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, paragraphs A.10.6.4 and A.11.1.1 and the National Volunteer Fire Council (NVFC) Health and Wellness Guide address these issues [NFPA 2007b; USFA 2004].

To overcome the financial obstacle, the Fire Department could urge current members to get annual medical clearances from their private physicians. Another option is having the annual medical evaluations completed by paramedics and EMTs from the local Emergency Medical Service (vital signs, height, weight, visual acuity, and EKG). This information could then be provided to a community physician (perhaps volunteering his or her time), who could review the data and provide medical clearance (or further evaluation, if needed). The more extensive portions of the medical evaluations could be performed by a private physician at the fire fighter's expense (personal or through insurance), provided by a physician volunteer, or paid for by the Fire Department. Sharing the financial responsibility for these evaluations between fire fighters, the Fire Department, and physician volunteers may reduce the negative financial impact on recruiting and retaining needed fire fighters.

***Recommendation #2: Ensure fire fighters are cleared for duty by a physician knowledgeable about the physical demands of firefighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.***

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2000]. According to these guidelines, the Fire Department should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty as required by NFPA 1500, Standard on Fire Department Occupational Safety and Health Program [NFPA 2007b]. The physician should review job descriptions and essential job tasks required for all Fire Department positions and ranks, in order 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. Since this incident, the State Fire Academy has implemented a program to ensure the medical clearance form for each trainee is on file prior

to allowing the trainee to participate in fire fighter training.

***Recommendation #3: Perform an annual physical performance (physical ability) evaluation to ensure fire fighters are physically capable of performing the essential job tasks of structural firefighting.***

NFPA 1500 recommends Fire Department members who engage in emergency operations be annually evaluated and certified by the Fire Department as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007b].

***Recommendation #4: Phase-in a comprehensive wellness and fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the National Volunteer Fire Council (NVFC)'s Health and Wellness Guide [NFPA 2008; IAFF, IAFC 2000; United States Fire Administration (USFA) 2004]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, reducing the number of work-related injuries, and reducing the number of work-related lost work days [Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005]. A recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars 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 in occupational injury/illness claims with additional savings expected from reduced future non-occupational healthcare costs [Kuehl 2007]. Given the Fire Department's structure, the NVFC program might be the most appropriate model. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

***Recommendation #5: Provide fire fighters with medical clearance to wear self-contained breathing apparatus (SCBA) as part of the Fire Department's medical evaluation program.***

The Occupational Safety and Health Administration (OSHA)'s Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection [29 CFR[1] 1910.134]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. Georgia does not operate an OSHA-approved State plan; therefore, public sector employers (including volunteer/paid fire departments) are not required to com-

ply with OSHA standards. Nonetheless, we recommend voluntary compliance with this OSHA standard.

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

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