



September 21, 2007

Fire Fighter Suffers Sudden Cardiac Death during Physical Fitness Training—North Carolina

SUMMARY

On December 1, 2006, a 44-year-old male career Fire Fighter (FF) was participating in physical fitness training in preparation for the Fire Department's annual physical fitness examination and the job-related physical agility test (JRPAT). After running (sprinting) for about 15 minutes he collapsed. A passerby alerted the fire fighters in the fire station. Crew members found the FF unresponsive, not breathing, and without a pulse (1748 hours). Dispatch was notified, cardiopulmonary resuscitation (CPR) and advanced life support were begun, and the FF was transported to the hospital's Emergency Department. Inside the Emergency Department, advanced life support treatment continued with no improvement in the FF's condition. The attending physician pronounced the FF dead at 1819 hours and resuscitation efforts were discontinued. The death certificate and autopsy (completed by the Medical Examiner) listed "hypertrophic obstructive cardiomyopathy" as the cause of death.

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unclear if any of these recommendations could have prevented the FF's sudden death.

- *Perform periodic medical evaluations consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments. The Fire Department and Union should negotiate the content and frequency of the evaluations to be consistent with NFPA 1582.*
- *Fire fighters should be medically cleared prior to participating in the Fire Department's physical fitness examination and the job-related physical agility test, specifically, by taking the aerobic capacity (treadmill) test.*
- *Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBAs).*

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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Fatality Assessment and Control Evaluation Investigation Report # F2007-10

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INTRODUCTION AND METHODS

On December 1, 2006, a 44-year-old male career FF died during physical fitness training. NIOSH was notified of this fatality on December 6, 2006 by the United States Fire Administration. NIOSH contacted the affected Fire Department on December 14, 2006 to obtain further information, and on March 22, 2007 to initiate the investigation. On April 30, 2007, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to North Carolina to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Health and Safety Officer
- Crew members
- FF'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
- Hospital records
- Death certificate
- Autopsy report

- Primary care provider medical records

INVESTIGATIVE RESULTS

On December 1, 2006, the FF arrived at his fire station (Station 23) for duty at 0745 hours; his shift began at 0800 hours. From 0800 hours to 0900 hours, the FF and his crew members cleaned the fire station and checked the apparatus and equipment. At 1021 hours, Engine 23 (including the FF) was dispatched to a medical call at a nursing home facility. The FF carried the medical equipment bag into the facility and assisted with patient care by taking vital signs of a facility resident. At 1037 hours, Engine 23 was released and returned to the fire station.

At 1345 hours, Engine 23 was dispatched to fill-in at Station 34 while Engine 34 was out of the station. While at Station 34, the FF and crew washed Engine 23. At 1545 hours, Engine 23 returned to their fire station. At 1642 hours, Engine 23 responded to its' medical call of the day. The incident involved an 8-year-old child with difficulty breathing. The FF carried the medical equipment bag inside the dwelling and took the child's vital signs. He then moved the child onto a stretcher and loaded the stretcher into the ambulance. Engine 23 was released from the scene at 1704 hours.

At 1720 hours, the FF asked his Captain for permission to go outside and exercise, in preparation for the annual Fire Department physical fitness examination and the job-related physical agility test. The FF changed from his station uniform into his exercise clothing. Station 23 was adjacent to a large parking lot, where he trained by running wind sprints. At 1745 hours, a passing motorist rang the front doorbell at Station 23 and alerted the Captain of Ladder 23 that there was a person down in



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the grass between the fire station and the church parking lot. Meanwhile, the motorist's spouse had walked to the rear of the station and advised the ambulance personnel (paramedics).

The Captain announced over the station's public address system that they had a "walk-in medical call." He then notified Dispatch via the hotline telephone and asked for a dedicated radio channel for emergency communication (1748 hours). Crew members retrieved their medical equipment (oxygen equipment and an automated external defibrillator [AED]), and, realizing that the "person down" was their FF crew member, alerted the Captain to that fact.

Paramedics found the FF unresponsive, not breathing, and without a pulse. CPR was begun while the AED was being attached. A shockable heart rhythm was read and a defibrillation "shock" was delivered. The AED did not advise to shock again and CPR continued. An oral airway was placed and oxygen was delivered via bag-valve-mask. Medic 24 was driven to the front of the station as the FF was placed onto a backboard/cot and placed into the Medic unit. CPR continued as an intravenous (IV) line was placed and cardiac resuscitation medications were given. The AED advised to shock again and a second defibrillation shock was delivered. Intubation (breathing tube inserted into the trachea) was attempted twice, but placement was unsuccessful. This was followed by the attempted placement of a laryngeal mask airway, but this was also unsuccessful. A cardiac monitor was attached, revealing ventricular fibrillation, and a manual shock was delivered. Medic 24 departed the scene at 1754 hours en route to the hospital's Emergency Department, and arrived 11 minutes later (1805 hours).

Inside the Emergency Department, advanced life support treatment continued, including intubation, an additional IV, and cardiac resuscitation medications. Cardiac monitoring revealed ventricular fibrillation multiple times, and numerous shocks (4-5) were administered. Despite these resuscitation measures, the FF's condition did not improve. At 1819 hours, the attending physician pronounced the FF dead, and resuscitation measures were discontinued.

Medical Findings. The death certificate and autopsy (completed by the Medical Examiner) listed "hypertrophic obstructive cardiomyopathy" as the cause of death. Pertinent findings from the autopsy, performed on December 2, 2006, included the following:

- Cardiomegaly (heart weighed 740 grams [g]; normal weight is <400 g)¹
- Left ventricular chamber reduced in size due to a mass of bulging muscle from the interventricular septum
- Eccentric left ventricular thickening of the interventricular septum (3.1 centimeters [cm]; normal thickness is 0.6–1.1 cm)²
- Left ventricular free wall thickened (1.7 cm; normal thickness is 0.76–0.88 cm)³ (normal echographic measurement is 0.6–1.1 cm)²
- Left ventricular front wall thickened (2.3–2.7 cm)
- Chronic ischemic damage involving the interventricular septum and left ventricular free wall (associated with scar formation)



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- Recent fibrous scar tissue formation along the anterior lateral free wall of the left ventricle resulting in mottling and hemorrhage
- Minimal atherosclerosis in the coronary arteries
- No evidence of a thrombus (blood clot) in the coronary arteries
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Negative drug tests

Microscopic examination of the heart revealed “extensive transmural scarring with loss of myocytes, hypertrophic changes of the residual myocytes, and focal myocyte disarray.”

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, this career Fire Department consisted of 972 uniformed personnel, and served a population of 665,000 in a 280-square-mile area. It had 38 fire stations, including 56 fire companies where fire fighters work 24-hour shifts (starting at 0800 hours) according to the following tour: 24 hrs-on, 24-off, 24-on, 48-off, 24-on, 24-off, 24-on, and 96-off. In 2006, the Fire Department responded to 85,194 calls. Engine 23 was the fourth busiest company within the Fire Department, responding to 3007 calls including: 201 fires, 1849 medical calls, 93 hazardous condition calls, 38 overpressure calls, 351 false alarm calls, 405 good intent calls, 212 service calls, and 28 natural/other calls. Engine 23 was sixth in fire responses. Engine 23 A-shift (the FF’s shift) responded to 1,507 calls. Station 23 was the busiest fire

station in the City, with about 6,300 responses. The ambulance service is provided by the County.

Membership and Training. The Fire Department requires all fire fighter applicants to

- be at least 18 years of age,
- possess a high school diploma or equivalent,
- possess a valid State Driver’s license,
- have no felony convictions or misdemeanors involving moral turpitude,
- have no illegal drug use in the past 12 months,
- complete an application,
- pass a written general knowledge test,
- pass a candidate physical ability test (CPAT),
- pass a background interview,
- pass a polygraph and background check,
- pass a panel interview,
- pass a pre-placement medical evaluation, and
- pass a drug screen.

The successful applicant is placed in a hiring pool and hired when an opening occurs. New hires are placed into the 21-week Recruit School. The successful graduate is trained to the NFPA FF-I and Emergency Medical Technician (EMT) level, is assigned to a fire company, and placed on probation for 12 months. The new fire fighter continues training for the next 3 years to achieve the NFPA FF-II



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level, and for an additional year to achieve the rank of FF/Engineer. All are certified to the EMT-defibrillator (EMT-D) level and are certified in CPR, AED use, and hazardous materials operations level (24-hour). The State voluntary minimum standard for fire fighter certification is NFPA 1001, *Standard for Firefighter Professional Qualifications*.⁴

The FF was certified as a Fire Fighter II, EMT-D, and in Hazardous Materials Operations. He had 17 years of firefighting experience.

Pre-placement Medical Evaluations. 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], sequential multiple analysis [SMA] 6, liver function tests, lipid test, and Hepatitis B antibody and antigen titer testing)
- Urine dipstick test
- Chest x-ray
- Resting electrocardiogram (EKG)
- Pulmonary function tests/spirometry
- Audiometry
- Vision test
- Tetanus booster (if appropriate)

These evaluations are performed by the Fire Department contract physician, who makes a decision regarding medical clearance for firefighting duties based on recommended standards in NFPA 1582. The Fire Department

is notified of any condition requiring modification or restriction. Results of the medical evaluation are kept confidential by the contract physician, and only the clearance status is reported to the Fire Department.

Periodic Medical Evaluations. Periodic medical evaluations are not required for all fire fighters. Biannual medical evaluations are required for Hazardous Material (Hazmat), Heavy Rescue, and Dive Team personnel. Components of this evaluation are the same as those of the candidate pre-placement medical evaluation. Hazmat personnel receive their annual medical evaluations per the State Occupational Safety and Health Administration (OSHA) Standard.⁵⁻⁶ Medical clearance for SCBA use is not required for all fire fighters, only for Hazmat, Heavy Rescue, and Dive Team.

If a fire fighter is injured at work, a return-to-duty medical clearance is required from the City's Worker's Compensation panel. If an injury or illness prevents a fire fighter from performing his or her duty for 30 calendar days, a return-to-duty clearance with no indicated or implied physical restrictions is required from their primary care physician. This clearance requires the signature of the treating physician on a Fire Department "Medical Clearance Form." This form includes a job description that lists many of the physically challenging job duties required during fire suppression or rescue work. The clearance is then reviewed by the Fire Department's Occupational Specialist, who makes the final clearance decision. At the Supervisor's discretion, depending upon the severity/nature of the injury/illness, regardless of the length of absence, a medical clearance with no indicated or implied physical restrictions may be required. This must be



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obtained from the fire fighter's primary care physician, using the Fire Department "Return-to-Work Medical Clearance" form. The Fire Department's Occupational Specialist reviews this clearance and makes the final return-to-duty decision. Employees involved in Worker's Compensation cases must provide proof of medical clearance from the City Department of Insurance and Risk Management. After receiving medical clearance, the employee must participate in and pass the job-related physical agility test in order to return to full duty.

Fire fighters who fail the job-related physical agility test are prescribed a physical reconditioning program designed by the Physical Fitness Coordinator. The fire fighter is assigned to the Fire Training Academy until they pass the job-related physical agility test. If the fire fighter cannot pass the job-related physical agility test within 30 days of assignment to the Academy, the situation is handled administratively on a case-by-case basis.

Health/Wellness. The Physical Fitness Coordinator administers the Fire Department's wellness/fitness program. A biannual physical fitness examination and a biannual physical agility test are required for members. The mandatory program is designed to meet the guidelines of the *Fire Service Joint Labor Management Wellness/Fitness Initiative*,⁷ and consists of an individualized exercise program developed by the Physical Fitness Coordinator based on the fire fighter's physical fitness examination (described below). Each fire fighter is encouraged to devote time to physical fitness training during each 24-hour shift (Sundays and holidays are optional). All fire

stations are equipped with exercise (strength and aerobic) equipment.

Physical Fitness Examination. The physical fitness examination evaluates fire fighters in three areas: aerobic capacity (treadmill to 15 [metabolic equivalent tasks] METs), muscle strength/ endurance, and body composition. The evaluation areas are weighted to generate a total/overall score, adjusted by gender and age. Exam results are utilized as follows:

- <50 on any item requires on-duty exercise participation in a prescribed program
- ≥50 on all items results in voluntary on-duty exercise participation
- ≥70 on all items results in the award of a uniform pin.

Job-Related Physical Agility Test. This test is administered biannually. During the job-related physical agility test, the participant wears full turnout gear, including SCBA. Participants either pass or fail the test based on time to completion. The job-related physical agility test consists of the following tasks:

- Pull a bundle of dry hose line (200-feet of 1¾-inch) from the truck shelf and place it on the ground. Pull a separate dry hose line (same size) 75-feet. Walk back to the truck.
- Remove a 16-foot ladder from the extended ladder bracket of the truck. Carry the ladder 75- feet. Raise the ladder to the wall. Walk to the stairwell of the fire tower.



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- Pick up a high-rise pack at the base of the stairwell (100-foot section of 1¾-inch hose formed into a “soft pack”). While carrying the high-rise pack, climb the stairs to the 4th floor of the tower. Drop the high-rise pack in the breezeway. Begin breathing air from the SCBA (remain on air for the remainder of the test).
- Enter into the 4th floor room off the breezeway. Advance to the nozzle end of the charged hose section (50-feet of 1¾-inch hose filled with water and capped off at both ends). Crawl through the 25-foot L-shaped course while dragging the charged hose section. When reaching the end of the course, pull the remainder of the hose section across the event finish line while remaining on at least one knee. Go to the ground floor and exit the tower.
- Climb a fixed pre-positioned ladder to the 2nd floor window of the tower. Enter through the window into the breezeway.
- Advance to the forcible entry simulator (Keiser machine) and move the I-beam the entire length of the sled.
- If the fire fighter is medically cleared, they are assigned to the Training Academy, under the supervision of the Chief of Training, for up to 90 days. During this period, the fire fighter will participate in an exercise regimen prescribed by the Physical Fitness Coordinator. The fire fighter may choose to take the job-related physical agility test at any time during the 90 days to return to full duty (if a passing time is achieved). After failure to successfully pass the job-related physical agility test within the initial 45 days, a meeting with the Fire Chief is scheduled.
- If the fire fighter is unable to pass the job-related physical agility test within 90 days, disciplinary action up to and including termination is possible.

DISCUSSION

Cardiomyopathies constitute a group of diseases involving damage to the heart muscle; damage not due to hypertension, ischemia (coronary artery), or valvular conditions.⁸ There are three types of cardiomyopathy based on functional impairment:

Failure to achieve a passing time (10 minutes or less) on the job-related physical agility test will result in the following actions:

- Immediate removal from operations duty assignment.
- A medical examination and medical clearance for duty determination. If the fire fighter is not medically cleared, the situation is handled as a medical fitness-for-duty issue.
- Dilated, the most common form, accounts for 60% of all CMs
- Hypertrophic (HCM), recognized by inappropriate left ventricular hypertrophy, often with involvement of the interventricular septum (as in this case)
- Restrictive, the least common form in Western countries, marked by impaired diastolic filling and in some cases with endocardial scarring of the ventricle⁸



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This FF was diagnosed with HCM at autopsy based on the location of his marked left ventricular hypertrophy, and the characteristic microscopic findings of myocyte disarray and focal scarification.⁹

Hypertrophic Cardiomyopathy (HCM).

Idiopathic HCM is a relatively rare heart condition, affecting approximately 0.2% of the population.¹⁰ Diagnosis is typically made by echocardiogram which shows the subaortic obstruction, and EKG findings of left ventricular hypertrophy by voltage. The majority of patients are asymptomatic, and sudden cardiac death is often the first clinical manifestation.¹¹ Risk factors for sudden death among idiopathic HCM patients include young age (<30 years old) at diagnosis, a family history of idiopathic HCM with sudden death, an abnormal blood pressure response to exercise, severe symptoms, non-sustained ventricular tachycardia, marked hypertrophy, marked left atrial dilatation, and genetic abnormalities associated with increased prevalence of sudden death.¹⁰⁻¹² Approximately half of the idiopathic HCM cases are transmitted genetically, typically as an autosomal dominant trait. Because of this, medical evaluation of first-degree relatives is warranted to determine whether screening tests (e.g., echocardiogram) are appropriate.

The FF was asymptomatic, and prior medical evaluations did not detect any cardiac abnormality (e.g., a heart murmur). The FF never had an EKG, either with the fire department or by his personal physician. The FF did not have any risk factors associated with sudden death among HCM patients.

The FF was running in wind sprints, which is considered a heavy level of physical

exertion.^{13,14} The NIOSH investigator concludes that the FF had a fatal cardiac arrhythmia associated with his hypertrophic obstructive cardiomyopathy. The heavy exertion associated with the wind sprints probably triggered his sudden cardiac death.

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 1582.¹⁵ NFPA considers idiopathic hypertrophic subaortic stenosis a Category A medical condition for fire fighter candidates. Candidates with Category A medical conditions “shall not be certified as meeting the medical requirements of NFPA 1582.”¹⁵ NFPA considers HCM a Category B medical condition for fire fighter candidates; defined as “a medical condition that, based on its severity or degree, **could** (our emphasis) preclude a person from performing as a fire fighter in a training or emergency operational environment by presenting a significant risk to the safety and health of the person or others.” Recently the medical community has determined that HCM and idiopathic hypertrophic subaortic stenosis are actually the same condition, the distinction only being the location of the hypertrophy. NFPA 1582 notes this distinction in its members section when it states, “Hypertrophic obstructive cardiomyopathy (idiopathic hypertrophic subaortic stenosis) might compromise the member’s ability to function as an integral component of a team, where sudden incapacitation can result in mission failure or in risk of injury or death to civilians or other team members.”¹⁵

NFPA recommends annual medical evaluations to include an EKG and a chest x-ray (as



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indicated). Had an EKG or chest x-ray been conducted as part of the Fire Department's annual medical evaluation, and offered to all fire fighters, perhaps the FF's enlarged heart would have been detected. This may have led to further medical evaluation (e.g., an echocardiogram) and possible treatment (an implantable cardiac defibrillator).

Had the FF's HCM been identified, would this have prevented his death? Although a variety of symptoms and medical tests can provide prognostic information, patients at greatest risk of sudden death or who are in need of antiarrhythmic therapy are hard to identify. Given the FF's lack of risk factors for sudden death, the low degree of efficacy of antiarrhythmic agents and their numerous side effects, and the lack of symptoms in the FF, it is unclear that a diagnosis would have led to treatment. Therefore, it is unclear if the FF's sudden death could have been prevented, even if his condition had been identified.

RECOMMENDATIONS

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unclear if any of these recommendations could have prevented the FF's sudden death.

***Recommendation #1:* Perform periodic medical evaluations consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments. The Fire Department and Union should negotiate the content and frequency of the evaluations to be consistent with NFPA 1582.**

NFPA 1582 requires fire departments to conduct pre-placement and annual medical evaluations. Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582¹⁵ and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) *Fire Service Joint Labor Management Wellness/Fitness Initiative*.⁷ However, the Fire Department is not legally required to follow this standard or this initiative.

Applying this recommendation involves economic repercussions. NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, Chapters 8-7.1 and 8-7.2¹⁶ addresses these issues.

***Recommendation #2:* Fire fighters should be medically cleared prior to participating in the Fire Department's physical fitness examination and the job-related physical agility test, specifically by taking the aerobic capacity (treadmill) test.**

During physical fitness examination tests, fire fighters are required to measure their aerobic capacity on a treadmill. When on the treadmill, fire fighters can exercise to the point of maximum heart rates and metabolic work of up to 15 metabolic equivalents of task (METs). This level of physical exertion can trigger heart attacks in susceptible individuals.¹⁷⁻²⁰ Therefore, we recommend fire fighters receive medical clearance prior to participating in the physical fitness examination.

***Recommendation #3:* Provide fire fighters with medical evaluations and clearance to wear self-contained breathing apparatus (SCBAs).**

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OSHA's *Revised Respiratory Protection Standard* requires employers to provide medical evaluations and clearance for employees using respiratory protection.²¹ Such employees include fire fighters who utilize SCBA in the performance of their duties. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. However, North Carolina is a State-plan State, and public sector employers are required to comply with OSHA standards.

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