



Volunteer Fire Fighter Suffers Sudden Cardiac Death During Fire Suppression at a Structural Fire – Indiana

SUMMARY

On March 22, 2003, a 62-year-old male volunteer Fire Fighter (FF) responded to a structural fire. The FF had conducted fire suppression activities on-scene for about 29 minutes when he began complaining of difficulty breathing and fatigue. He presented himself to the on-scene ambulance, where he suddenly collapsed. Approximately 20 minutes later, despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) administered on-scene, en route, and at the hospital, the FF died. The autopsy report, completed by a pathologist, stated the FF “died of acute, occlusive thrombosis of the left circumflex coronary artery secondary to coronary artery atherosclerosis.” The physical stress of fire fighting and the underlying atherosclerotic coronary artery disease (CAD) contributed to this fire fighter’s cardiac arrest and sudden death.

The first four recommendations below are preventive measures recommended by other fire service groups to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. The next recommendation addresses a potential safety issue related to this particular event. The final recommendation addresses a potential safety issue unrelated to this particular event.

- **Conduct pre-placement and periodic medical evaluations to determine medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.**

- **Conduct Exercise Stress Test (EST) for FFs with two or more risk factors for CAD.**
- **Phase in a mandatory wellness/fitness program for FFs to reduce risk factors for cardiovascular disease and improve cardiovascular conditioning.**
- **Perform pre-placement and annually, a physical performance (physical ability) evaluation on ALL FFs to ensure they are physically capable of performing the essential job tasks of structural fire fighting.**
- **Ensure that FFs are cleared for duty by a physician knowledgeable about the physical demands of fire fighting and the various components of National Fire Protection Association (NFPA) 1582 and that the results of the exam are discussed with the FF.**
- **Provide FFs with medical evaluations and clearance to wear self-contained breathing apparatus (SCBA).**

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 www.cdc.gov/niosh/firehome.html or call toll free 1-800-35-NIOSH



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INTRODUCTION AND METHODS

On March 22, 2003, a 62-year-old male volunteer FF collapsed at a structural fire. Approximately 20 minutes later, despite CPR and ALS administered on the scene, en route, and at the hospital, the FF died. On March 28, 2003, NIOSH contacted the affected Fire Department (FD) to initiate the investigation. On July 20, 2004, an Occupational Nurse Practitioner from the NIOSH Fire Fighter Fatality Investigation Team and an Occupational Medicine Resident from the University of Cincinnati traveled to Indiana to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel spoke with the following people:

- Fire Chief
- Crew members
- FF's wife and daughter

During the site visit NIOSH personnel reviewed the following records:

- FD incident report
- Emergency medical service (ambulance) incident report
- Hospital Emergency Department record
- Death certificate
- Autopsy report
- Medical records of the FF
- FD standard operating procedures
- FD training records
- FD annual report (2002 and 2003)

INVESTIGATIVE RESULTS

Incident. On March 22, 2003, at approximately 0328 hours an alarm sounded alerting volunteer fire fighters to a fire in their area. A 62-year-old male volunteer FF arrived on the scene in his privately-owned vehicle (POV) at 0334 hours. He was wearing his turnout gear, but not his SCBA. He pulled a 2½-inch supply hose from the engine to the hydrant approximately 150 feet

away. After pulling the hose, he relieved another fire fighter spraying the exterior of the structure for about 5 minutes utilizing a 1½-inch half hose. After relinquishing control of the hose line, he began pacing the alley that bordered the structure. Telling a nearby fire fighter that he was not feeling well, they both walked to the FF's POV. He did not provide any more details and after drinking sips of water he stated he was going to the on-scene ambulance for evaluation.

He had been on scene about 29 minutes. The two FFs reached the ambulance at approximately 0403 hours, and the FF told the paramedics he was not feeling well and was having difficulty breathing. The paramedics noted the FF to be pale, cold, clammy, diaphoretic (sweaty), and restless, with rapid, labored respirations. At this point the FF collapsed. He was carried to the back of the ambulance where cardiac monitoring revealed a junctional heart rhythm. His pulse was characterized by the paramedics as regular rhythm and normal quality. Oxygen was administered via a non-rebreather face mask and an intravenous line (IV) was established.

At approximately 0411 hours, the FF's cardiac rhythm converted to ventricular tachycardia, but he remained conscious and alert. At 0413 hours, his heart rhythm degenerated into ventricular fibrillation (a rhythm incompatible with life) and paramedics began CPR. He was defibrillated twice, after which he regained a pulse and spontaneous breathing. The ambulance departed the fire ground at approximately 0415 hours for transport to the nearest hospital. While en route the FF's heart rhythm again degenerated into ventricular fibrillation; further defibrillation attempts were unsuccessful at converting the lethal rhythm. Various ALS medications were administered but they also failed to restore a viable heart rhythm. The FF received airway



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support in the form of bag-valve mask ventilation with 100% oxygen during the 15-minute transport to the hospital, as repeated intubation (breathing tube placed in the throat to maintain airway) attempts were unsuccessful. Despite being in ventricular fibrillation and not intubated, the EMS personnel reported an oxygen saturation of 97% on pulse oximetry monitoring during transport.

Upon arrival at the hospital at 0430 hours, the FF's heart rhythm was unresponsive with no heart beat. At 0432 hours, the FF was intubated, with correct placement verified via auscultation. He was administered another round of ALS medication without change in his condition. At 0435 hours the FF was pronounced dead, and resuscitation efforts were discontinued.

Medical Findings. The autopsy, performed by a pathologist, listed "occlusive thrombosis of the left circumflex coronary artery secondary to coronary artery atherosclerosis" as the cause of death. Pertinent findings from the autopsy performed on March 23, 2004, included:

- Moderate to severe coronary atherosclerosis as detailed below:
 - o Acute occlusive thrombus present within the mid to distal portion of the left circumflex coronary artery
 - o 80%-95% stenosis of the distal left anterior descending coronary artery and the right posterior descending coronary artery
 - o Intraplaque hemorrhage at the mid portion of the left anterior descending coronary artery
 - o 40%-60% stenosis of the mid portions of left anterior, left circumflex, and right coronary arteries
- Cardiomegaly (enlarged heart weighing 550 grams, normal is less than 400 grams)
 - o Extensive biventricular dilatation

- o Concentric left ventricular hypertrophy (LVH)
- Negative drug and alcohol test results
- Carboxyhemoglobin level (a measure of carbon monoxide exposure) of 2.2% (10 hours after the initiation of oxygen). The normal lab value for moderate to heavy smokers is 4-15%. The FF did have a history of smoking.

The FF had the following risk factors for CAD: family history, male gender, smoking, hypercholesterolemia, physical inactivity, and obesity (Body mass index [BMI] of 30.6 kilogram/meters², A BMI above 30 kg/m² indicates obesity)¹. At the time of death, the FF had been taking a beta-blocker medication prescribed for heart palpitations.

In June 1999, the FF presented to the hospital's emergency department with palpitations and a rapid heart rate. He was hospitalized to rule out a heart attack, medically known as a myocardial infarction (MI). After a heart attack had been ruled out via blood tests and electrocardiogram (EKG), he underwent an echocardiogram that showed mild to moderate LVH and left atrial enlargement with a normal ejection fraction (normal 55% or higher). To determine whether the FF had underlying ischemic heart disease, an exercise stress test (EST) was performed utilizing the Bruce protocol. The FF exercised for 8 minutes 42 seconds achieving 10.4 metabolic equivalents (METS). The test was stopped at Stage III due to fatigue and attainment of his maximum predicted heart rate. During the test the FF never complained of angina, had a good blood pressure response, and showed no ischemic EKG changes. However at the 3.5 minute mark, the FF had some arrhythmias (frequent asymptomatic ventricular bigeminy) that resolved spontaneously after 1 minute. After these tests, the FF was discharged from the hospital with a diagnosis of rapid heart



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rate, chest palpitations, and “history of tobacco abuse.” The consulting cardiologist felt the FF’s symptoms were due to supraventricular tachycardia (SVT), one type of heart arrhythmia of unclear etiology, but possibly due to multiple etiologies: tobacco, hypertension, and alcohol. The FF was discharged, prescribed one aspirin daily, and with instructions to follow-up for management of cardiac etiologies.

Over the next 2 years he had occasional recurrence of his palpitations for which a heart medication (a beta blocker) was prescribed. During this time he was also diagnosed with high blood cholesterol for which a low fat diet was prescribed. His most recent blood tests in October 2001 showed: total cholesterol 219 mg/dL (normal is 51 mg/dL-200 mg/dL), HDL 38 mg/dL (normal is 35 mg/dL -150 mg/dL), LDL 163 mg/dL (normal is 0 mg/dL -130 mg/dL), and triglycerides 253 mg/dL (normal is 35 mg/dL-160 mg/dL).

In February 2002, the FF was noted to have an elevated blood glucose level of 141 mg/dL (normal 72 mg/dL-99 mg/dL). It is unclear if this test was a “fasting” blood sugar, but it suggests diabetes mellitus. Finally, the FF was occasionally noted to have an elevated systolic blood pressure (>140 mm Hg), but this was not consistently noted and his physician never diagnosed him with hypertension. None of these evaluations mentioned medical clearance for fire fighting duties.

According to his wife and fellow crew members, the FF did not complain of any symptoms in the days leading up to this incident.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the FD consisted of 16 volunteer fire fighters serving a population of 800 in a geographic area of 5 square miles. There was one fire station. In 2003 the

department responded to 12 calls, of which 10 were fire calls and 2 were medical standbys.

Training. A new FF applicant must complete a department application, after which the FD membership votes whether to accept the applicant. Once accepted, the applicant has 1 year to attend the 24-hour initial fire training class required to be on the fire ground. The applicant then has 1 year to complete Fire Fighter I class. This course consists of twelve 3-hour sessions. Once Fire Fighter I is completed, the applicant returns to the FD for further mentoring in vehicle operations, SCBA use, hose, and ladders.

Medical Evaluations. The FD does not require a pre-placement medical evaluation nor a physical ability test for applicants, new members, or current members. However, fire fighters are encouraged to obtain a complete physical examination through their employer or at their own expense. Medical clearance for SCBA use is not required. FFs injured on duty or who become ill and miss work, must be cleared for return to work by their personal physician. There is no fitness equipment available at the fire station. No wellness program is available for the fire fighters.

DISCUSSION

Coronary Artery Disease (CAD) Risk Factors and the Pathophysiology of Sudden Cardiac Death.

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.² Risk factors for CAD development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure (systolic >140 millimeters of mercury [mmHg] or diastolic > 90 mmHg), high blood cholesterol (total cholesterol > 240 milligrams per deciliter [mg/dL]), obesity/physical inactivity, and diabetes.^{3,4} The FF had six of these risk factors, and possibly



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diabetes mellitus and hypertension. He had previously complained of heart “palpitations” and was being treated with a beta blocker, but he did not complain about any symptoms the night before his death. Unfortunately, sudden cardiac death is the initial presentation in up to 20% of cases of CAD.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.⁵ However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.⁶ 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.⁷ This sudden blockage is primarily due to blood clots (thrombosis) forming on the top of atherosclerotic plaques. Blood clots, or thrombus formation, in coronary arteries are initiated by disruption of atherosclerotic plaques. Certain characteristics of the plaques (size, composition of the cap and core, presence of a local inflammatory process) predispose the plaque to disruption.⁷ Disruption then occurs from biomechanical and hemodynamic forces, such as the increased blood pressure, increased heart rate, increased catecholamines, and shear forces that occur during heavy exercise.^{8,9} The FF had a thrombus on autopsy (left circumflex coronary artery), thus confirming the occurrence of an MI.

Firefighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.¹⁰ Firefighting activities are strenuous and often require fire fighters to work at near maximal heart rates for long periods. The increase in heart rate has been shown to begin with responding to the initial alarm and to persist through the course of fire suppression activities.¹¹⁻¹³ Even when energy

costs are moderate (as measured by oxygen consumption) and work is performed in a thermoneutral environment, heart rates may be high (over 170 beats per minute) owing to the insulative properties of the personal protective clothing.¹⁴ This FF responded to a structural fire wearing full turnout gear. He deployed a 2½-inch supply hose from the engine to the hydrant located approximately 150 feet away, then relieved another fire fighter spraying the exterior of the structure for about 5 minutes utilizing a 1½-inch half hose. This is considered a very heavy level of physical exertion.¹⁵⁻¹⁷ Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.¹⁸⁻²¹ The physical stress of fire fighting and his underlying atherosclerotic CAD contributed to this fire fighter’s cardiac arrest and sudden death.

Use of Exercise Stress Tests (EST) to Screen for CAD. To reduce the risk of heart attacks and sudden cardiac arrest among fire fighters, the NFPA has developed the NFPA 1582 guideline entitled *Comprehensive Occupational Medicine Program for Fire Departments*.²² NFPA 1582 recommends fire fighters with two or more risk factors for CAD (family history of premature [less than age 60] cardiac event, hypertension, diabetes mellitus, hypercholesterolemia [total cholesterol greater than 240 mg/dL or HDL cholesterol less than 35 mg/dL], and cigarette smoking) be screened for obstructive CAD by an EST.²² These recommendations are similar to those of the American College of Cardiology/American Heart Association (ACC/AHA).

Since the FF had three and possibly all five of the NFPA 1582 risk factors for CAD, an EST would have been recommended. Although the FF had an EST in June 1999, it is possible that a more recent EST would have identified his CAD and possibly



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led to further evaluation and therapy that could have prevented his sudden cardiac death.

In addition to his CAD and thrombus, other important autopsy findings were an enlarged heart (550 grams), both hypertrophied and dilated. Both hypertrophic and dilated cardiomyopathies are associated with sudden cardiac death.²³ It is possible that these cardiomyopathies contributed to this FF's sudden cardiac death, but his untimely death is much more likely due to an MI-induced heart arrhythmia. Sudden cardiac death is associated with myocardial infarctions due to the instability of the heart's conduction system.

Although an EKG in April 2000 mentioned normal sinus rhythm with occasional premature supraventricular complexes, and the consulting cardiologist's impression was supraventricular tachycardia (SVT), no diagnosis was ever made of SVT by the primary care physician. Instead rapid heart rate and chest palpitations were chosen as the discharge diagnosis. No further cardiology work-up for SVT was completed.

According to NFPA 1582, SVT is a condition that, based on its severity, could preclude fire fighter tasks. This standard is suggested strictly for candidates, which the FF was in 2000, 1 year after his hospital admission and SVT discovery. Furthermore, NFPA 1582 states that members of a fire department should be examined to ensure that SVTs do not interfere with their ability to perform certain essential job tasks. If this FD had been performing pre-placement and periodic medical examinations, it is possible the FF may have been precluded from active fire fighting.

RECOMMENDATIONS

The recommendations are presented in order of priority. The first four recommendations below are preventive measures recommended by other

fire service groups to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. The next recommendation addresses a potential safety issue related to this particular event. The final recommendation addresses a potential safety issue unrelated to this particular event.

Recommendation #1: Conduct pre-placement and periodic medical evaluations to determine FF medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others.

The purpose of periodic medical evaluations is to ensure that fire fighters have the ability to perform duties without presenting a significant risk to the safety and health of themselves or others. Guidance regarding the content and scheduling of periodic medical examinations for fire fighters can be found in NFPA 1582.²² In addition to providing guidance on the frequency and content of the medical evaluation, NFPA 1582 provides guidance on medical requirements for persons performing fire fighting tasks. Applying NFPA 1582 involves legal and economic issues, so it should be carried out in a **confidential, nondiscriminatory** manner. Appendix D of NFPA 1582 provides guidance for Fire Department administrators regarding legal considerations in applying the standard.

This recommendation involves economic repercussions and may be particularly difficult for small, rural, volunteer fire departments to implement. To overcome the financial obstacle, the FD could urge current members to get annual medical clearances from their private physicians. Another option is to ask the volunteer FFs to complete the brief annual medical evaluations recommended by NFPA 1582 themselves. The FFs would complete the medical and occupational history portions, and EMT's from the county's emergency medical service would complete the



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portions for vital signs, height, weight, visual acuity and resting EKG. This information could then be provided to a community physician, perhaps volunteering his or her time, to review the data and provide medical clearance (or further evaluation, if needed). The more extensive medical examinations could be performed by a private physician at the fire fighter's expense, provided by a physician volunteer, or paid for by the FD. Sharing the financial responsibility for these evaluations between volunteers, the FD, and willing physician volunteers should reduce the negative financial impact on recruiting and retaining needed volunteers. These and other suggestions can be found in the National Volunteer Fire Council (NVFC) and United States Fire Administration's (USFA) *Health and Wellness Guide for the Volunteer Fire Service*, FA-267/January 2004.²⁴

Furthermore, a city employee must be designated to administer the pre-placement and annual medical evaluations and follow-up on their outcomes. This employee must maintain the confidentiality of the medical records. If this employee is a member of the FD and participating in the City's annual medical evaluation, a policy should prevent him/her from self administering the program.

Recommendation #2: Conduct EST for FF with two or more risk factors for CAD.

We recommend EST for fire fighters at higher risk for CAD. In the following paragraphs we state the recommendations of other organizations to enable you to make an informed decision on this controversial topic.

Conducting EST on asymptomatic individuals is controversial.²⁵ As mentioned above, NFPA 1582 recommends, not as a part of the requirements but for informational purposes only, that all

fire fighters with two or more risk factors for CAD be given an EST. NFPA 1582 lists the following criteria for CAD risk factors: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (diastolic blood pressure greater than 90 mm Hg), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).²²

The ACC/AHA recommends EST for (1) asymptomatic men over the age of 40 with a history of cardiac disease (as a screening test before beginning a strenuous exercise program), and (2) men over age 40 with one or more risk factors.²⁶ They define five risk factors for CAD: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic greater than 140 mmHg or diastolic greater than 90 mm Hg), smoking, diabetes, and family history of premature CAD (cardiac event in first-degree relative less than 60 years old).²⁶ The AHA/ACC states that the evidence to conduct EST in asymptomatic individuals with diabetes mellitus is "Class IIa: there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/opinion is in favor."²⁶ The ACC/AHA go on to say the evidence is "less well established" (Class IIb) for the following groups:

1. Evaluation of persons with multiple risk factors as a guide to risk-reduction therapy with the risk factors essentially the same as the NFPA listed above
2. Evaluation of asymptomatic men older than 45 years, and women older than 55 years:
 - Who are sedentary and plan to start vigorous exercise
 - Who are involved in occupations in which impairment might jeopardize public safety [e.g. fire fighters]
 - Who are at high risk for CAD due to other



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diseases (e.g., peripheral vascular disease and chronic renal failure)²⁶

Another organization weighing in on the subject is the U. S. Department of Transportation (DOT). To obtain medical certification for a commercial drivers license, the DOT recommends EST for drivers over the age of 45 with more than two CAD risk factors.²⁷

The U.S. Preventive Services Task Force (USPSTF) does not recommend EST for asymptomatic individuals, even those with risk factors for CAD; rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes).²⁸ The USPSTF indicates that there is insufficient evidence to recommend screening middle age and older men or women in the general population but notes that “screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety.”²⁸

Recommendation #3: Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular conditioning.

Physical inactivity is the most prevalent modifiable risk factor for CAD in the United States. Additionally, physical inactivity, or lack of exercise, is associated with other risk factors: obesity and diabetes.²⁹ NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*, and NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Fighters*, require a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.^{30,31} In 1997, the International Association of Fire Fighters (IAFF) and the International Association

of Fire Chiefs (IAFC) published a comprehensive *Fire Service Joint Labor Management Wellness/Fitness Initiative* to improve fire fighter quality of life and maintain physical and mental capabilities of fire fighters. Ten fire departments across the United States joined this effort to pool information about their physical fitness programs and to create a practical fire service program. They produced a manual and a video detailing elements of such a program.³² The Fire Department should review these materials to identify applicable elements. Other large-city negotiated programs can also be reviewed as potential models. The NVFC/USFA *Health and Wellness Guide for the Volunteer Fire Service* addresses the special circumstances affecting volunteer departments.²⁴ The Guide provides further documentation supporting fire fighter health and also gives suggestions for program initiation and features. Small volunteer fire departments should review the programs and documents mentioned above and determine which components are practical for them.

Recommendation #4: Perform, pre-placement and annually, a physical performance (physical ability) evaluation on ALL FFs to ensure they are physically capable of performing the essential job tasks of structural fire fighting.

NFPA 1500 requires fire department members who engage in emergency operations to be annually evaluated and certified by the fire department as meeting the physical performance requirements identified in paragraph 10.2.³⁰

Recommendation #5: Ensure that FFs are cleared for duty by a physician knowledgeable about the physical demands of fire fighting and the various components of NFPA 1582 and that the results of the examination are discussed with the fire fighter.

Frequently, private physicians are not familiar



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with a fire fighter's job duties or with guidance documents such as NFPA 1582. To ensure physicians are aware of these guidelines, we recommend that the FD provide contract and private physicians with a copy of NFPA 1582. In addition, we recommend the FD carefully evaluate the opinion of the private physician regarding return to work. This decision requires knowledge not only of the medical condition but also of the fire fighter's job duties. Lastly, we recommend that all return-to-work clearances be reviewed by a FD-contracted physician. Thus, the final decision regarding medical clearance for return to work lies with the FD physician with input from many sources including the FF's private physicians.

Recommendation #6: Provide FFs with medical evaluations and clearance to wear SCBA.

OSHA's Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection.³³ These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans. Indiana is a State-plan State; therefore, public sector employers are required to comply with OSHA standards. A copy of the OSHA medical checklist has been provided to the FD.

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