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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 27, 2001*

Driver/Operator Suffers a Cardiac Arrest During a Wildland Fire Exercise – Georgia

SUMMARY

On November 16, 2000, a 49-year-old male Driver/Operator (D/O) participated in a wildland fire exercise as part of the United States Forest Service Wildland Fire Fighter "red card" certification. After cleaning debris from the plowline, the D/O collapsed. Despite cardiopulmonary resuscitation (CPR) and advanced life support (ALS) performed on the scene by crew members and paramedics, and by hospital personnel at the emergency department (ED), the victim died. The death certificate, completed by the Medical Examiner, listed "atherosclerotic cardiovascular disease" as the immediate cause of death. The autopsy report, completed by the Medical Examiner, listed "heart rhythm disturbance (arrhythmia)" as the cause of death and "atherosclerotic cardiovascular disease" as the contributing factor.

The following recommendations address some general health and safety issues identified during this investigation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job heart attacks and sudden cardiac arrest among fire fighters. These selected recommendations have not been evaluated by NIOSH, but represent published research, consensus votes of technical committees of the National Fire Protection Association (NFPA) or fire service labor/management groups. Issues relevant to this Fire Department include

- ***Incorporate exercise stress tests into the Fire Department's periodic medical evaluation program.***
- ***Clear Fire fighters for duty by a physician knowledgeable about the physical demands of fire fighting and the various components of NFPA 1582.***
- ***Phase in a mandatory wellness/fitness program for fire fighters to reduce risk factors for cardiovascular disease and improve cardiovascular capacity.***

INTRODUCTION AND METHODS

On November 16, 2000, a 49-year-old male Driver/Operator died after suffering a cardiac arrest while performing fire fighting activities at a wildland fire exercise. On January 18, 2001, NIOSH contacted the affected Fire Department to initiate the investigation. On March 21, 2001, a Safety and Occupational Health Specialist and an Epidemiologist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Georgia to conduct an on-site investigation of the incident.

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During the investigation, NIOSH personnel interviewed the following:

- The Fire Chief
- The Union representative
- Crew members on duty with the victim
- The victim's family

During the site visit NIOSH personnel reviewed

- Fire Department policies and operating guidelines
- Fire Department training records
- Fire Department annual report for 2000
- Fire Department physical examination records maintained by the Preventive Medicine clinic
- Victim's medical records maintained by his private physician
- Ambulance response report
- Hospital records
- Death certificate
- Autopsy report

INVESTIGATIVE RESULTS

Incident. On November 16, 2000, the victim completed his 24-hour shift at 0800 hours. He and two other crew members from the involved Fire Department were scheduled to participate in a wildland fire exercise as part of the US Forest Service "red card" certification process. They were joined by 13 personnel from neighboring fire departments that formed the Georgia Mutual Aid Group (GMAG), in addition to local emergency medical personnel. At 0830 hours, a prebriefing was held to make assignments and to survey the area to be burned. Over 20 personnel were on the scene; they were divided into two squads. An instructor, Liaison, Safety, Medical, and Engine Support positions completed the roster.

The burn area was level ground, comprised of grass, and measured approximately 200 by 100 feet. The plow lines (area cleared of all vegetation by a tractor and plow) were approximately 200 feet long, and the hand line (area cleared of all vegetation by shovels and rakes) was approximately 100 feet long. The victim was assigned as Squad 1 Leader. At 0945 hours, both squads dug a hand line approximately 100 feet long, which took approximately 2 hours. Crew members were wearing forestry gear (Nomex coat and pants, leather boots, wildland helmet, and leather gloves) weighing approximately 10 lbs. During this time, the victim did not report any symptoms suggestive of heart problems. At approximately 1130 hours, the victim returned to his station for a break, and, after approximately 15 minutes, returned to the exercise site.

On the scene, the fire was set, but the grass would not burn. The squads' skills at digging hand lines were assessed, and the hand line was abandoned. Both squads were then assigned to clean debris from the plow line. During this phase, at 1153 hours, the victim collapsed. He had a seizure that lasted approximately 1 minute, and then he stopped breathing. His squad carried him to the corner of a nearby parking lot while the IC notified Dispatch of a man down, and the Safety Officer notified the ambulance from the neighboring city. (This ambulance service has a primary emergency medical response agreement with this military installation).

Initial assessment of the victim by crew members revealed that he was unresponsive, not breathing, and pulseless. Cardiopulmonary resuscitation (CPR) (chest compressions and assisted ventilations via bag-valve-mask) was begun. Engine 22 and Rescue 2 were dispatched at 1155 hours and arrived on the scene at 1157 hours. The victim was found to be unresponsive, not breathing, and pulseless, and CPR was in progress. Oxygen (100%) was administered, an automated external defibrillator (AED) was attached to the victim, and he was placed on a backboard. Three electrocardioversions (shocks)

were delivered with no change in patient status. The ambulance arrived, and the victim was loaded into the ambulance while advanced life support (ALS) measures (intubation, IV, and resuscitation medications) were initiated. Another defibrillation was administered, and a normal sinus rhythm was obtained for approximately 30 seconds, but the victim's heart then stopped beating (asystole). The ambulance departed the scene enroute to the hospital at 1230 hours and CPR and ALS continued while enroute.

Once the victim was inside the hospital's emergency department (ED), a cardiac monitor revealed ventricular fibrillation. Six additional shocks were administered, but no pulse was regained. The victim was pronounced dead by the attending physician at 1250 hours, and resuscitation efforts were stopped.

Medical Findings. The death certificate, completed by the Medical Examiner, listed "atherosclerotic cardiovascular disease" as the immediate cause of death.

Pertinent findings from the autopsy report, completed by the Medical Examiner, are listed below:

- Atherosclerotic cardiovascular disease
  70 % stenosis, left main coronary artery
  70-90 % stenosis, multi-focal, left anterior descending coronary artery
  complete occlusion, circumflex coronary artery
- Vascular congestion, all internal organs

Medical records indicated that the victim had seven risk factors for coronary artery disease (CAD): male gender, advanced age (greater than 45 years old), smoking, family history of CAD, hypertension, high cholesterol, and lack of regular physical activity. The victim was not prescribed antihypertensive or cholesterol-lowering medications. On April 17, 2000, a routine occupational physical examination revealed a change in his cholesterol and blood pressure. (His blood pressure went from 137/83 mm/Hg in 1998 to 157/63 mm/Hg, and his cholesterol level went from 190 mg/dl in 1998 to 259 mg/dl). A chest X-ray revealed the heart and great vessels were within normal limits. He was subsequently evaluated by his personal physician and returned to duty.

The victim had not expressed any signs or symptoms of chest pain or discomfort to his family, coworkers, or health care providers. On November 15, the day before the victim's sudden death, he reported for work at 0800 hours. Throughout the day, he performed equipment checks on his pumper (Engine 11), after which he attended a meeting and training. At 1425 hours, Engine 11 responded to a motor vehicle accident (car struck a deer). The victim and his crew members checked the driver of the vehicle, who refused further treatment. At 1451 hours, Engine 11 responded to a smell of gas in a building. The victim remained with the Engine as the building was checked by the crew members. No hazardous condition was found and the Engine returned to quarters. No other responses occurred during his shift. However, the victim related to his coworkers that he had remained awake most of the night due to both occupational and nonoccupational stress.

DESCRIPTION OF THE FIRE DEPARTMENT

At the time of the NIOSH investigation, the Fire Department, situated on two local military installations, consisted of 30 uniformed career personnel. The Department served a total population of 10,000 residents on the two military installations in a total geographic area of 3 square miles. There are two fire stations (one located at each of the two military installations, which are approximately 15 miles apart). Fire fighters, including the victim, work one of two shifts from 0800-0800 hours, and work 24

hours on duty, 24 hours off duty, for six tours and are then off duty for 3 days.

In 1999, the Department responded to 1,274 calls: 421 false alarms, 304 other fires, 240 rescue calls, 142 hazardous condition/standby calls, 72 other calls, 66 trouble alarms, 11 prescribed burns, 8 gas leaks, 3 vehicle fires, 3 mutual aid (off-installation) calls, 2 electrical fires, 2 refuse fires, and 1 grass fire. The station to which the victim was assigned responded to 707 calls: 300 other fires, 162 rescue calls, 116 false alarms, 89 hazardous condition/standby calls, 11 prescribed burns, 10 trouble alarms, 8 gas leaks, 3 vehicle fires, 3 mutual aid (off-installation) calls, 2 electrical fires, 2 refuse fires, and 1 grass fire.

Training. The Fire Department requires all new fire fighters to pass a preemployment physical examination (discussed below). The new fire fighter must be precertified to the level required by the vacant position. Subsequent training is conducted on the shift. Fire fighters certified in hazardous materials (Hazmat), CPR, and EMT are recertified annually. The victim was certified as a Fire Fighter II, EMT, Hazmat, and Driver/Operator, and he had 17 years of fire fighting experience. He was currently serving as a Sergeant and a Driver/Operator.

Preemployment/Preplacement Evaluations. The Department requires a preemployment/preplacement medical evaluation for all new hires, regardless of age. Components of this evaluation include the following:

- History
- Vital signs
- Physical examination
- Blood tests: complete blood count (CBC), metabolic profile, lipid profile, and liver function battery
- Urine Tests: urine dip stick and urinalysis
- Pulmonary function test
- Resting electrocardiogram (ECG)
- Chest X-ray
- Audiometry
- Vision test

These evaluations are performed by the installation physician, who makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the Fire Department.

Periodic Evaluations
Periodic medical evaluations are required annually by this Department. Components of this are the same as the preplacement evaluation, except a chest X-ray is not included. These evaluations are performed by the installation physician, and the medical clearance decision for each examination is forwarded to the Fire Department. If an employee is injured at work or ill, the employee is evaluated and must be cleared for "return to work" by the installation physician. Input from the employee's private physician is considered at this point. As described earlier, the victim's last Fire Department medical examination was in April, 2000. Due to his increased blood pressure and cholesterol, he was referred to his private physician. After this evaluation, his physician recommended that he be returned to full duty.

The installation has exercise (strength and/or aerobic) equipment which can be used by fire fighters while on duty. However, the Fire Department does not have a mandatory exercise/fitness program. Wellness programs (smoking cessation, weight control, high blood pressure, diabetes, or cholesterol) are also offered by the installation.

DISCUSSION

In the United States, coronary artery disease (atherosclerosis) is the most common risk factor for cardiac arrest and sudden cardiac death.[1] Risk

factors for its development include age over 45, male gender, family history of coronary artery disease, smoking, high blood pressure, high blood cholesterol, obesity, physical inactivity, and diabetes.[2] The victim had seven of these risk factors.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades.[3] However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion.[4] 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.[5] This sudden blockage is primarily due to blood clots (thrombosis) forming on top of atherosclerotic plaques. The victim's autopsy report identified complete occlusion of the circumflex artery. However, no thrombus was identified.

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.[5] Disruption then occurs from biomechanical and hemodynamic forces, such as increased blood pressure, increased heart rate, increased catecholamines, and shear forces, which occur during heavy exercise.[6,7]

Fire fighting is widely acknowledged to be one of the most physically demanding and hazardous of all civilian occupations.[8] Fire fighting 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 persist through the course of fire suppression activities.[9-11] Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks.[12-16] The victim had assisted in digging a hand line and then with clearing debris from the plow line; this is considered "moderate to heavy work," requiring 5-7 metabolic equivalents (METS).[13,17-19]

Psychologic and physiologic stress have been associated with increased risk of cardiovascular disease: gastrointestinal, musculoskeletal, and emotional disorders; workplace injury; and impaired immune function.[20,21] The victim related to crew members that he was experiencing a large amount of occupational and nonoccupational stress. The day prior to his collapse, the victim worked a 24-hour shift and had reportedly stayed awake late into the night due to these stress factors.

The Department requires a preemployment/preplacement medical examination for all new hires and annual medical evaluations. The annual medical evaluations/examination program differs in two ways from National Fire Protection Association (NFPA) Standard 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians. First, while NFPA recommends annual medical evaluations, they recommend extensive medical examinations on a periodic basis according to the age of the fire fighter (less than 30: every 3 years; 30-39: every 2 years; over 40 years: every year).[22] The second difference with NFPA 1582 is that NFPA 1582 recommends fire fighters over the age of 35 with risk factors for CAD undergo an EST.[22]

The EST can be used to screen individuals for obstructive CAD. Unfortunately, it has problems with both false negatives (inadequate sensitivity) and false positives (inadequate specificity), particularly for asymptomatic individuals (individuals without symptoms suggestive of angina), young men, and women.[23,24] Despite these problems, NFPA 1582 nevertheless recommends EST for fire fighters without risk factors for CAD beginning at age 40.[22]

Other expert groups do **not** recommend EST for asymptomatic individuals without risk factors for CAD.[25-27]

When these asymptomatic individuals **have** risk factors for CAD, recommendations vary by organization. NFPA recommends biannual EST for fire fighters with CAD risk factors beginning at age 35.[22] The medical certification for the commercial drivers license (CDL) issued by the Department of Transportation (DOT) recommends EST for drivers over the age of 45 with more than two CAD risk factors.[25] Since the victim was a Driver/Operator for the Fire Department, this regulation would seem to have relevance, but miliary installations and municipal fire departments are exempt from the DOT regulations.[28] In addition, the DOT medical advisory criteria are just that, advisory. The American College of Cardiology/American Heart Association (ACC/AHA) identifies four groups for EST, although they note that the "usefulness/efficacy is less well established by evidence/opinion."[26]

- Group 1: Persons with multiple risk factors. Five risk factors for CAD are defined: hypercholesterolemia (total cholesterol greater than 240 mg/dL), hypertension (systolic greater than 140 mm Hg 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).

- Group 2: Men over the age of 40 and women over the age of 50 (especially if sedentary) who plan to start vigorous exercise.

- Group 3: Men over the age of 40 and women over the age of 50 who are at high risk for CAD due to other diseases (e.g., chronic renal failure).

- Group 4: Men over the age of 40 and women over the age of 50 who are involved in occupations in which impairment might impact public safety.

The victim had the criteria to meet the conditions of Group 1 and Group 4.

Finally, 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).[27] The USPSTF indicates that evidence is insufficient to recommend screening middle age and older men or women in the general population; however, "screening individuals in certain occupations (pilots, truck drivers, etc.) can be recommended on other grounds, including the possible benefits to public safety.[27]

It is possible that an EST on the victim would have identified his CAD and, if treatment were initiated, might have prevented his sudden cardiac death.

RECOMMENDATIONS

The following recommendations address health and safety issues identified during this investigation. This list includes some preventive measures that have been recommended by other agencies to reduce the risk of on-the-job cardiac arrest among fire fighters. These recommendations have not been evaluated by NIOSH but represent published research or consensus votes of Technical Committees of the National Fire Protection Association or labor/management groups within the fire service.

Recommendation #1: Incorporate exercise stress tests into the Fire Department's medical evaluation program.

NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians, and the International Association of Fire Fighters/International Association of Fire Chiefs (IAFF/IAFC) wellness/fitness initiative both recommend at least biannual EST for fire fighters.[22,29] They recommend that these tests begin at age 35 for those with CAD risk factors and at age 40 for those without CAD risk factors. The EST could be conducted by the fire fighter's personal physician (at Fire Department expense) or the installation physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the installation physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Recommendation #2: Clear Fire fighters for duty by a physician knowledgeable about the physical demands of fire fighting and the various components of NFPA 1582.

Physicians providing input regarding medical clearance for fire fighting duties should be knowledgeable about the physical demands of fire fighting and familiar with the consensus guidelines published by NFPA 1582, Standard on Medical Requirements for Fire Fighters and Information for Fire Department Physicians. To ensure private physicians are aware of these guidelines, we recommend that the installation Preventive Medicine Clinic provide the private physicians with a copy of NFPA 1582. In addition, we recommend the installation Preventive Medicine Clinic not automatically accept the opinion of the employee's private physician regarding return to work. This decision requires knowledge not only of the employee's medical condition but also the employee's job duties. Frequently, private physicians are not familiar with an employee's job duties or guidance documents such as NFPA 1582. Thus, the final decision regarding medical clearance for return to work lies with the installation physician with input from many sources, including the employee's private physician.

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

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being.[30] The International Association of Fire Fighters (IAFF) and the International Association of Fire Chiefs (IAFC) joined in 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.[29] The Wellness/Fitness Initiative provides guidance regarding wellness program content, to include physical examination and evaluation, fitness, and behavioral health. Stress management and prevention is a key component of behavioral health. Stress management should address such issues as job stress, family relations, financial concerns, and personal concerns.[21,29] Wellness programs have been shown to be cost effective, typically by reducing the number of work-related injuries and lost work days.[31-33] A similar cost savings has been reported by the wellness program at the Phoenix Fire Department, where a 12-year commitment has resulted in a significant reduction in their disability pension costs.[34]

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