F2007 22

NIOSH

Fire Fighter Fatality Investigation and Prevention Program

Death in the line of duty...

A Summary of a NIOSH fire fighter fatality investigation March, 2008

After Working Three Consecutive 24-Hour Shifts and Fighting an Extensive Structure, a 47-Year Old Career LT Suffers Sudden Cardiac Death During Physical Fitness Training – California

SUMMARY

From January 17 until the morning of January 20, 2007 a 47-year old career LT worked for three 24-hour consecutive shifts. During those shifts his assigned company responded to 22 emergency calls which precluded the LT from getting much sleep during the late evening and early morning hours. Approximately 11 hours before his death, the LT fought a residential structure fire. During the search/rescue and knockdown phase of the fire, the LT was wearing his turnout gear and his self-contained breathing apparatus (SCBA). However, during the overhaul phase, the LT removed his SCBA. After getting off duty on January 20, 2007 the LT drove himself to the local gymnasium were he began exercising. After riding the exercise bike for about 20 minutes, he collapsed. Gymnasium employees immediately found him unresponsive without a heart beat or respirations. 9-1-1 was called and the club's automated external defibrillator (AED) was retrieved. Despite cardiopulmonary resuscitation (CPR) performed at the gym including the use of the AED, and advanced life support performed in the ambulance and in the emergency department of the local hospital, the LT died. The death certificate, completed by the Deputy County Coroner, listed the immediate cause of death as "cardiac insufficiency" with "cardiac arrhythmia" as an underlying cause, and "atrial fibrillation" as another significant condition contributing to the death but not the underlying cause. No autopsy was performed.

NIOSH investigators agree with the conclusions of the Deputy County Coroner, and believe that vigorous exercise and carbon monoxide exposure during fire suppression could have also contributed to his death.

It is unlikely the following recommendations could have prevented the LT's untimely death. Nonetheless, NIOSH investigators offer these recommendations to improve upon the FD's already comprehensive health and safety program.

- ***Use respiratory protection during the entire overhaul operation or until direct reading instruments measure levels of carbon monoxide below occupational exposure limits.***

- ***Limit the number of consecutive shifts a FF can work.***

After Working Three Consecutive 24-Hour Shifts and Fighting an Extensive Structure Fire, a 47-Year Old Career LT Suffers Sudden Cardiac Death during Physical Fitness Training – California

- ***Consider using coronary artery disease (CAD) risk factors, rather than age alone, to determine the onset and frequency of exercise stress tests.***
- ***Discuss with local union representatives ways to increase participation in the FD's fitness program and how to improve the wellness program.***
- ***Perform an autopsy on all on-duty fire fighter fatalities.***

INTRODUCTION & METHODS

On January 20, 2007, a 47-year-old male LT suffered sudden cardiac death while performing physical fitness training after working three consecutive shifts. On January 25, NIOSH was notified of the fatality and, in February 2007, contacted the affected FD to gather information regarding the fatality. On August 27, an occupational medicine physician from the NIOSH Fire Fighter Fatality Investigation and Prevention Team traveled to California to conduct an on-site investigation of the incident.

During the investigation NIOSH personnel met with or interviewed the following people:

- Fire Chief
- FD Administrative Services Manager
- Secretary/Treasurer of the local chapter of the International Association of Fire Fighters (IAFF)
- Crew members on-duty with the LT
- Battalion Chief on-duty with the LT
- Family members of the LT
- One of the LT's personal physicians

During the site visit NIOSH personnel reviewed the following documents related to this incident:

- FD investigation file of the incident
- Station 8 incident reports for January 17-20, 2007
- FD incident report for the resuscitation effort
- Death certificate
- County Sherriff / Coroner's report
- State of California, Doctor's first report of occupational injury or illness

INVESTIGATIVE RESULTS

On January 17, 2007, at 0800 hours, the LT arrived at his fire station (Station 8) for a 24-hour "overtime" shift (Shift A). Station 8 was staffed with eight fire fighters working one ladder truck and one engine. The LT was the officer assigned to the engine. During the 24-hour shift the LT and his engine crew responded to 11 emergencies, including one structure fire, one mutual aid request, one smoke scare, and eight emergency medical service (EMS) calls. The engine was out of the station for 4½ hours while responding to these emergency calls which occurred throughout the day, evening, night, and early morning hours of January 18, 2007. At no point during this shift did the LT indicate to co-workers that he was having any health problems.

On January 18, at 0800 hours, the LT started his regular shift (Shift B) at Station 8. Again, the LT was the officer assigned to the engine along with three other crewmembers. During this 24-hour shift, the engine responded to five emergencies including two smoke/gas odors calls and three EMS calls. The engine was out of the station for approximately 1-¾ hours while responding to these calls throughout the day, evening, night and early morning hours of January 19, 2007. At no point during this second 24-hour shift did the LT express any signs or symptoms of a health problem.

The LT had previously agreed to cover the "C" shift for the ladder truck officer, so on January 19, at 0800 hours, the LT started his third consecutive 24-hour shift. During this 24-hour shift, the truck responded to six emergencies including two structure fires, two utility-related calls, and two EMS calls. The ladder truck was out of the station for about 4-½ hours while responding to these emergencies; the majority of the time (three hours) was spent responding to the structure fire described below. The engine from Station 8 responded to 17 emergencies during the same 24-hour period.

At 2212 hours, the ladder truck was dispatched to a house fire at a single family home of approximately 1100 square feet. The air temperature was approximately 50º Fahrenheit with minimal wind. The ladder truck arrived at 2217 hours and noted smoke showing and active fire from the B side of the home with the front door open. The LT assumed initial command of the incident and sent his crewmembers to ventilate the roof. Station 8's engine arrived a few seconds later, hooked up to the nearest water hydrant, and positioned the engine at the front of the home as the crew prepared for interior attack. A few seconds later the Battalion Chief arrived and assumed command of the incident.

The LT was re-assigned to conduct search and rescue inside the structure with the interior attack team. In full turnout gear and using air from his self-contained breathing apparatus which weighed approximately 60-65 pounds, the LT searched each room, but did not find any occupants in the building after searching for about 10 minutes. He exited the structure and assisted with positioning an air blower at the front door to increase ventilation of the structure. The interior attack team found the fire confined to the kitchen and proceeded with extinguishment.

Knockdown of the fire took approximately 20-30 minutes. Heat, smoke, and soot damage was observed throughout the dwelling, but the fire damage was confined to the kitchen. At about 2245 hours overhaul began on the roof, but was delayed inside the house for about an hour for the fire investigator's inspection. During this hour, the LT accompanied the fire investigator throughout the house (wearing turnout gear but not his self-contained breathing apparatus), and then climbed into the attic and onto the roof to assist crewmembers overhauling the roof. Overhaul operations ceased at approximately 0030 hours and units returned to quarters.

Station 8 crewmembers cleaned and re-stored their equipment and then showered. Station 8's engine responded to emergency EMS calls throughout the early morning hours. At no point during this shift did the LT complain or show signs of any health problems.

The LT left Station 8 at approximately 0800 hours and headed to the local gym. The LT exercised regularly (daily or at least every other day) as part of the FD's fitness and wellness program. During the three continuous 24-hour shifts described above, the LT spent approximately 1 hour each shift stretching and using the aerobic exercise equipment (treadmill and elliptical machine) in Station 8. At approximately 0845 hours the LT began using the exercise bike. Witnesses described the LT as sweating profusely. He vomited, and collapsed off the bike at about 0910 hours. The gym staff noted he was unresponsive without a pulse. 9-1-1 was called (0911 hours) as the gym staff placed an AED on the LT. Two shocks were delivered with no change in the LT's clinical condition. The gym staff then initiated CPR.

EMS units from the FD arrived at 0915 hours and found the LT unresponsive with no pulse, no breathing, and CPR in progress. Oxygen was initially provided by a bag-valve-mask while a cardiac monitor was attached. The monitor showed a heart rhythm of "pulseless electrical activity." At 0919 hours paramedics successfully placed a breathing tube into the LT's airway (intubation) on the second attempt. Proper placement of the tube was confirmed by auscultation, esophageal detector device, and exhaled carbon dioxide detector device as recommended by the American Heart Association [AHA 2005]. An intravenous line was established through which medications consistent with advanced life support were administered. CPR continued until the transporting ambulance company arrived at 0926 hours. Despite CPR and advanced life support performed at the gym, in the ambulance, and in the emergency department of the local hospital, the LT's clinical condition did not improve. He was pronounced dead at 1009 hours and resuscitation efforts were discontinued.

The death certificate, completed by the Deputy County Coroner, listed the immediate cause of death as "cardiac insufficiency" with "cardiac arrhythmia" as an underlying cause, and "atrial fibrillation" as another significant contributing condition. No autopsy was performed. According to the records available to NIOSH at the time of this report, no toxicology tests were performed (e.g., carboxyhemoglobin levels or drug screen).

Medical Findings. The LT had a history of atrial fibrillation first diagnosed in 1997 by an electrocardiogram (EKG) taken during the FD's annual medical evaluation. He was taken off-duty pending a cardiac evaluation. The cardiologist performed an echocardiogram and an exercise stress test, both of which were reported as normal. The LT was prescribed one baby aspirin per day and returned to full duty four days later.

In 2001, atrial fibrillation was again noted by an EKG taken during the FD's annual medical evaluation. The LT was taken off-duty for two weeks and eventually underwent direct current cardioversion (shock) in September, 2001. From 2001 to 2004, the LT was prescribed a number of antiarrhythmic medications; in February 2004 he underwent a surgical procedure known as ablation to control his persistent atrial fibrillation. The LT was last seen by his personal cardiologist in November 2006. At the time of his death he was taking flecainide, an antiarrhythmic and rate-limiting prescription medication.

Medical records available to the NIOSH investigator at the time of this report suggested that the LT's only risk factor for coronary artery disease was obesity. He weighed 272 pounds with a height of 6 feet, giving him a body mass index of 36.9 kilograms per meters^2 (kg/m^2) [CDC 2008]. Although a body mass index of 30.0-39.9 kg/m^2 generally is considered obese, this method of determining obesity may overestimate body fat in individuals with a muscular build [NHLBI 2008a].

DESCRIPTION OF THE FIRE DEPARTMENT

This FD consists of 586 uniformed personnel in 25 stations serving a population of 411,000 residing within 52-square-miles. Operational components of the FD include: hazardous materials response, water rescue, heavy rescue, medical response, structural fire fighting, wildland fire fighting, shipboard fire fighting, aircraft rescue/fire fighting, and terrorism/weapons of mass destruction response. The FD typically responds to about 60,000 emergency calls each year, 80% of which are medical emergencies.

To become a fire fighter within this FD, applicants must complete an application, pass a written examination, pass two interviews by panels of FD and municipal officials, pass a physical ability test (Appendix A), pass a background check, pass a psychological evaluation, and be medically cleared for duty (described below) before being accepted into the recruit class. The recruit class must complete the 16 week Fire Academy administered by the FD. After passing the Fire Academy, the fire fighter is assigned to a fire station as a probationary employee. After twelve months of satisfactory performance as a probationary employee, the fire fighter becomes a member of the FD.

Post-offer/Pre-placement Medical Evaluation. The FD requires a post-offer/pre-placement medical evaluation conducted by a physician group under contract with the FD. Components of this medical evaluation include the following:

- Complete medical and occupational history
- Height, weight, and vital signs
- Physical examination
- Blood tests: complete blood count, chemical panel (SMA 18), and lipid panel
- Urine drug screen (amphetamines, barbiturates, cocaine metabolites, marijuana metabolites, methadone, opiates, phyencyclidine, propoxyphene, and alcohol)
- Resting EKG (12 lead)
- Chest X-ray (one posterior-anterior view)
- Pulmonary function tests
- Audiogram
- Vision titmus test
- Tuberculin skin test
- Hepatitis B and C antibody screening tests

Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD's personnel director. The LT joined the FD in 1990. At the time of his death he had 16 years of fire fighting experience.

Annual Medical Evaluation. Every fire fighter has an annual medical evaluation by the same contract physicians group conducting the post-offer / pre-placement medical evaluation. The components of the annual evaluation are the same as the post-offer / preplacement evaluation except that chest x-rays are not done unless clinically indicated, and an exercise stress test (e.g., a treadmill) test is done for fire fighters over the age of 40 every other year. Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and respirator use, then forwards this decision to the FD's personnel director. The LT was evaluated in 2006 and cleared for fire fighting duties, but, at the time of this report, the NIOSH investigator did not have access to the LT's exercise stress tests results.

Health/Wellness. As mentioned earlier, the FD requires candidates to pass a physical ability test, and requires the same test for members. The FD provides exercise equipment (strength and aerobic) in all their fire stations and allows fire fighters to exercise for about 1½ hours while on-duty. However, use of the equipment is voluntary, and the Fire Chief estimates that about 40% of fire fighters exercise while on-duty. According to his crewmembers, the LT exercised regularly while on-duty, typically using the treadmill and elliptical machines each shift. Wellness education is provided by the contract physicians group conducting the medical evaluation, however some of the fire fighters mentioned the scope of the effort could be improved.

DISCUSSION

Atrial Fibrillation

Definition - Atrial fibrillation is a disturbance of the heart's conduction system. During atrial fibrillation, the heart's two small upper chambers (the atria) beat very rapidly in a non-productive, quivering manner. The heart's AV node blocks many of the atrium's electrical signals from traveling to the heart's ventricles. However, enough electrical signals get through the AV node to result in a rapid and irregular heart beat described by many patients as palpitations [Waktare 2002]. Other symptoms associated with atrial fibrillation include fatigue and lethargy.

Atrial fibrillation can occur in three different patterns: paroxysmal, persistent, or permanent. Paroxysmal atrial fibrillation occurs in episodes lasting seconds to days, and resolve spontaneously. Persistent atrial fibrillation does not stop spontaneously. Permanent atrial fibrillation describes the condition when the heart's normal sinus rhythm cannot be restored despite treatment.

Treatment - There are three major treatment considerations for atrial fibrillation. The first involves returning the heart to a normal (sinus) rhythm by prescribing antiarrhythmic medications (e.g., flecainide, amiodarone, etc.), or administering a shock (direct current cardioversion). If these efforts fail to restore sinus rhythm, other treatments may include ablation surgery (selective elimination of one or more sites in the atria to reduce the recurrence of atrial fibrillation) and/or the placement of a cardiac pacemaker [Oral 2006; Ames 2006].

The second treatment consideration involves reducing the number of impulses transmitted through the AV node by prescribing "rate limiting" medications (e.g. digoxin, beta-blockers, etc.). The third treatment consideration involves preventing blood clots thereby reducing the risk of stroke. The risk of blood clots can be reduced by prescribing anticoagulant drugs (i.e., coumadin) or anti-platelet drugs (i.e., aspirin).

Risk Factors - Atrial fibrillation has been associated with caffeine use, alcohol use, hyperthyroidism, and obesity, but by far the most important and strongest risk factors are the presence of other heart conditions [Wang 2004; Frost 2005; Fuster 2006]. These predisposing heart conditions include coronary artery disease (CAD), heart valve problems, heart failure, left atrial enlargement, and hypertension. When younger patients (less than age 60) are diagnosed with atrial fibrillation, between 20-45% have no associated predisposing cardiac conditions [Levy 1999]. There has been one reported case of atrial fibrillation associated with acute exposure to fire smoke [Bass 1979].

Prognosis - The prognosis for persons with atrial fibrillation depends on a number of factors including the type of atrial fibrillation and the presence of predisposing conditions. Stroke is the most common and one of the serious complications. Atrial fibrillation patients with an underlying heart valve problem have a 17-fold increased risk of a stroke [Fuster 2006]. However, in young patients without any of the predisposing factors listed above or diabetes mellitus, the risk of stroke is estimated to be 1% and only aspirin is recommended for stroke prevention [Fuster 2006].

As mentioned earlier in this report, the LT was first diagnosed with atrial fibrillation in 1997 by an EKG taken during the FD's annual medical evaluation. He was asymptomatic at this time. Subsequent cardiac evaluation revealed no underlying heart conditions. Given his age (38 years old) and lack of heart problems, NIOSH investigators agree with the decision to return the LT to full duty on one baby aspirin per day (anti-platelet medication).

The LT's asymptomatic paroxysmal atrial fibrillation developed into persistent atrial fibrillation with fatigue and lethargy. From 2001 to 2004, the LT tried direct current cardioversion, and the use of anti-arrhythmic and rate-limiting medications. In 2004 he underwent surgical ablation and was placed on restricted duty. Heart rhythm tracings over the next two months showed that the ablation surgery reduced, but did not eliminate, the atrial fibrillation. The partial success of the ablation allowed the LT to discontinue his anticoagulant medication and return to full duty.

Sudden Cardiac Death. Most cases of sudden cardiac death are related to coronary heart disease and/or a heart attack (myocardial infarction). Establishing the occurrence of a heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In the LT's case, he never regained a heart rhythm on which an EKG could reveal characteristic changes, cardiac enzyme testing was not performed (but we would not expect the enzymes to become positive for at least 4 hours post-heart attack), and no autopsy was performed to find a coronary artery thrombus [AHA 2008a]. In the setting of a heart attack (acute myocardial infarction), atrial fibrillation increases the risk of sudden cardiac death [Gronefeld 2000; Pedersen 2006].

Although a heart attack was possible, NIOSH investigators consider this unlikely given the LT only had two (male gender and obesity) of the many risk factors for CAD [AHA 2008b]. In the absence of a heart attack or other predisposing cardiac conditions, atrial fibrillation, by itself, is not associated with sudden cardiac death [Hagens 2006]. Since the LT probably did not have a heart attack and did not have any of the predisposing cardiac conditions, why did the LT suffer sudden cardiac death?

One possibility is the presence of an "accessory pathway" in the atrium's conduction system (e.g., Wolf-Parkinson-White syndrome). This accessory pathway can allow the very fast electrical signals in atrial fibrillation to bypass the AV node, resulting in rapid ventricular rates that can degenerate into lethal ventricular fibrillation [Fuster 2006]. Although possible, NIOSH investigators consider the presence of an accessory pathway unlikely because the LT had no suggestion of such a pathway on EKG or noted during the ablation surgery.

Another possible explanation for the LT's sudden death is a complication from his atrial fibrillation or its treatment. For example, stroke is a common complication and has been associated with sudden death [Phillips 1977]. Although an autopsy would have been able to rule out this complication, NIOSH investigators consider this unlikely due to the accounts of how the LT collapsed.

Another complication of atrial fibrillation could be a side effect of flecainide, the LT's antiarrhythmic medication. Flecainide has been reported to increase the risk of some ventricular arrhythmias (ventricular proarrhythmias) and convert atrial fibrillation to atrial flutter with rapid conduction through the AV node, both of which could cause sudden cardiac death [Van Gelder 1989; Fuster 2006]. However, the LT did not have any of the factors predisposing to drug-induced ventricular proarrhythmias, and this side effect is relatively rare [Fuster 2006].

Eleven hours prior to his death the LT was involved in fire suppression and exposed to fire smoke during overhaul without the protection of his SCBA. High levels of carbon monoxide are present in fire smoke, not only during the knockdown phase, but also during overhaul [Bolstad-Johnson 2000]. Carbon monoxide has been reported to exacerbate CAD, trigger heart attacks, increase ventricular arrhythmias, and lower the threshold for ventricular fibrillation [DeBias 1976; Atkins 1986; Marius-Nunez 1990; Sheps 1990]. Because the LT's blood was not tested for evidence of carbon monoxide poisoning, it is not possible to assess whether such exposure was a factor in his death. However, if carbon monoxide poisoning played a role in the LT's death, he should have collapsed shortly after his exposure on the fire ground, rather than 9 hours later.

The LT died during fitness training. Epidemiologic studies in the general population have found that heavy physical exertion can trigger a heart attack and cause sudden cardiac death [Tofler 1992; Willich 1993; Mittleman 1993; Albert 2000]. Epidemiologic studies among fire fighters have shown that fire suppression, training, alarm response, and strenuous physical activity on the increased the risk for a sudden cardiac event [Kales 2003; Hales 2007a; Kales 2007]. The LT was involved in heavy physical activity during fire suppression 11 hours prior to his death, and involved in strenuous physical exertion during his fitness training.

Based on the findings discussed above, the NIOSH investigator concluded that the LT died from a cardiac arrhythmia due to a combination of his underlying cardiac conduction abnormality, heavy physical exertion and possible exposure to carbon monoxide during fire suppression and heavy physical exercise during this fitness training program.

RECOMMENDATIONS

It is unlikely the following recommendations could have prevented the LT's untimely death. Nonetheless, NIOSH investigators offer these recommendations to improve upon the FD's already comprehensive health and safety program.

Recommendation #1: Use respiratory protection during the entire overhaul operation or until direct reading instruments measure levels of carbon monoxide below occupational exposure limits.

Overhaul fire smoke contains a number of hazardous substances including irritants, asphyxiates (e.g., carbon monoxide, cyanide, etc.) and several probable/possible human carcinogens (e.g., formaldehyde, benzene, etc.) [Jankovic 1991; Kinnes 1998; Bolstad-Johnson 2000; Austin 2001]. Because of the variety of toxins present in overhaul fire smoke, complete respiratory protection requires the continuous use of an SCBA. However, the continuous use of an SCBA over a long period of time increases the risk of fire fighter fatigue, overexertion, heat stress, and injuries. In addition, refilling empty cylinders (bottles) presents logical problems during extensive overhaul operations.

Ideally, a direct reading instrument could instantaneously measure all the hazardous components of fire smoke. When all measurements reach safe or non-detectible levels, fire fighters could safely doff their SCBA. Unfortunately, such an instrument does not exist. Therefore, some FDs require SCBA use during overhaul until direct reading instruments measure carbon monoxide concentrations ≤ 50 or ≤ 35 parts per million (ppm) [Kinnes 1998; Cook 2006; Hales 2007b]. However, low concentrations of carbon monoxide do not always correlate with low concentrations of the other constituents of fire smoke during overhaul [Bolstad-Johnson 2000]. This had led some to recommend continuous SCBA use, or SCBA use until carbon monoxide concentrations are < 150 ppm, then require the use of air purifying respirators equipped with cartridges appropriate for particulates, aldehydes, acid gases, and organic vapor until overhaul is complete [Bolstad-Johnson 2000; Carter 2001].

Recommendation #2: Limit the number of consecutive shifts a FF can work.

In 2004, NIOSH reviewed the literature on the health effects of overtime and extended work shifts (typically 12-hour shifts compared to 8-hour shifts). Overtime was associated with poorer perceived general health, increased injury rates, more illnesses, or increased mortality in 16 of 22 studies reviewed [NIOSH 2004]. Extended work shifts were associated with decreased alertness, increased fatigue, lower cognitive function, declines in vigilance, and increased injuries [NIOSH 2004]. Studies among physicians who worked very long shifts (>24 hours) reported deteriorating cognitive performance, more frequent patient errors, and more frequent motor vehicle accidents after their shift [NIOSH 2004; Barger 2005, Barger 2006].

Prior to his death, the LT worked three consecutive 24-hour shifts. While the LT was able to get some sleep during these shifts, his sleep was interrupted by the numerous emergency runs that his company made during the night and early morning hours. In addition, his sleep was interrupted by the station's alarm for emergency runs conducted by the other company in the station. There are no data linking chronic sleep deprivation with sudden cardiac death. However, chronic sleep deprivation could result in a decline in cognitive function, possibly impairing judgment during incident command or fire suppression. Allowing fire fighters to work consecutive shifts may represent not only an injury and illness risk issue for individual fire fighters, but also a safety and health risk for their coworkers.

Recommendation #3: Consider using CAD risk factors, rather than age alone, to determine the onset and frequency of exercise stress tests.

The FD currently conducts exercise stress tests on fire fighters above the age of 40. If negative, these tests are repeated every other year. While age is an important risk factor for CAD, it is not the only risk factor. Male gender, family history, diabetes mellitus, high blood cholesterol, hypertension, smoking, lack of exercise, and obesity are other important risk factors [AHA 2008b]. The initiation and frequency of exercise stress tests should be determined by the number and severity of all the CAD risk factors.

National Fire Protection Association (NFPA) 1582 recommends screening for CAD risk factors and exercise stress tests for **some** asymptomatic (i.e., no symptoms of angina) fire fighters [NFPA 2007a]. Conducting exercise stress tests on asymptomatic individuals is somewhat controversial due to the possibility of false positive and false negative test results [Gibbons 2002]. For informational purposes only NFPA 1582 recommends a symptom limiting exercise stress test for male fire fighters over the age of 45 with two or more risk factors for CAD, and for female fire fighters over the age of 55 with two or more risk factors for CAD. The 1582 standard lists the following criteria for CAD risk factors: hypercholesterolemia [total cholesterol greater than 240 milligrams per deciliter (mg/dL)], hypertension [systolic greater than 140 millimeters of mercury (mm Hg) or diastolic greater than 90 mm Hg], smoking, diabetes, or family history of premature CAD (cardiac event in first degree relative less than 60 years old).

This recommendation is similar to that of the American College of Cardiology/American Heart Association (ACC/AHA) [Gibbons 2002]. The ACC/AHA considers the evidence to be in favor of conducting exercise stress tests in asymptomatic individuals with diabetes mellitus, but "less well established" (Class IIb) for:

1. Asymptomatic men older than 45 years, and women older than 55 years who are sedentary and plan to start vigorous exercise;
2. Asymptomatic men older than 45 years, and women older than 55 years who are involved in occupations in which impairment might jeopardize public safety (e.g., fire fighters);
3. Asymptomatic men older than 45 years, and women older than 55 years who are at high risk for CAD due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

An alternative approach is to conduct exercise stress tests on asymptomatic fire fighters based not only on the number of risk factors, but on their severity. Web-based tools can be used to assess risk [NHLBI 2008b]. Some authors recommend exercise stress tests for asymptomatic individuals at "intermediate risk" of a heart attack or sudden cardiac death (e.g., risk between 0.6% to 2.0% per year) [Lauer 2005].

The U. S. Department of Transportation (DOT) provides guidance about stress tests for those seeking medical certification for a commercial drivers license. The DOT expert medical panel recommends stress tests for asymptomatic "high risk" drivers [Blumenthal 2007]. They define high risk drivers as those with any of the following:

- Diabetes mellitus
- Peripheral vascular disease
- Person above the age of 45 with multiple risk factors for coronary heart disease
- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force does not recommend stress tests for asymptomatic individuals, even those with risk factors for coronary artery disease. Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [Fowler-Brown 2004].

Recommendation #4: Discuss with local union representatives ways to increase participation in the FD's fitness program and how to improve the wellness program.

NFPA 1500 requires a wellness program that provides health promotion activities for preventing health problems and enhancing overall well-being [NFPA 2007b]. 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 [Maniscalco 1999; Stein 2000; Aldana 2001, IOM 2005]. Fire service health promotion programs have been shown to reduce coronary artery disease risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey 2002; Womack 2005; Blevins 2006]. One mandatory program showed a cost savings of $68,741 due to reduced absenteeism [Stevens 2002]. A recent study conducted by the Oregon Health and Science University reported a savings of over one million dollars for each of four large FDs implementing the IAFF/IAFC wellness/fitness program compared to four large FDs not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future non-occupational healthcare costs [Kuehl 2007].

Guidance on how to implement components of a comprehensive wellness and fitness program, and how to increase participation can be found from the following sources:

- NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters [NFPA 2008];
- International Association of Fire Fighters/ International Association of Fire Chiefs (IAFF/IAFC), Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF/IAFC 2000].

Recommendation #5: Perform an autopsy on all on-duty fire fighter fatalities.

In 2008 the United States Fire Administration (USFA) released its revised *Firefighter Autopsy Protocol* [US Fire Administration 2008]. With this publication, the USFA hopes to provide "a more thorough documentation of the causes of firefighter deaths and achieve three goals:

1. It will advance the analysis of the causes of firefighter deaths to aid in the development of improved firefighter health and safety equipment, procedures, and standards;

2. It will help determine eligibility for death benefits under the Federal government's Public Safety Officer Benefits Program, as well as state and local programs; and

3. It will address an increasing interest in the study of deaths that could be related to occupational illnesses among firefighters, both active and retired."

REFERENCES

AHA, International Liaison Committee on Resuscitation (ILCOR) Advanced Life Support Task Force [2005]. Part 4: Advanced Life Support. Circulation *112*:III-25-III-54.

AHA [2008a]. Blood tests for rapid detection of heart attacks. Dallas, TX: American Heart Association. [http://www.americanheart.org/presenter.jhtml?identifier=4477]. Date accessed: February 19, 2008.

AHA (American Heart Association) [2008b]. Risk factors and coronary artery disease.[http://www.americanheart.org/presenter.jhtml?identifier=4726]. Date accessed: February 19, 2008.

Albert CM, Mittleman MA, Chae CU, Lee IM, Hennekens CH, Manson JE [2000]. Triggering of sudden death from cardiac causes by vigorous exertion. N Engl J Med *343*:1355-1361

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot *15*:296-320.

Ames A, Stevenson WG [2006]. Catheter ablation of atrial fibrillation. Circulation *113*:e666-668. Available online at http://circ.ahajournals.org/cgi/reprint/113/13/e666. Accessed on April 24, 2008.

Atkins EH, Baker EL [1985]. Exacerbation of coronary artery disease by occupational carbon monoxide exposure: a report of two fatalities and a review of the literature. Am J Ind Med *7*:73-79.

Austin CC, Wang G, Ecobichon DJ, Dussault G [2001]. Characterization of volatile organic compounds in smoke at municipal structure fires. J Tox Environ Hlth *63*:437-458.

Barger LK, Ayas NT, Cade BE, Cronin JW, Rosner B, Speizer FE, Czeisler CA [2006]. Impact of extended-duration shifts on medical errors, adverse events, and attentional failures. PLoS Med *3*:e487. [http://medicine.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pmed.0030487&ct=1]. Accessed on: February 19, 2008.

Barger LK, Cade BE, Ayas NT, Cronin JW, Rosner B, Speizer FE, Czeisler CA; Harvard Work Hours, Health, and Safety Group [2005]. Extended work shifts and the risk of motor vehicle crashes among interns. N Eng J of Med *352*:125-34.

Bass HN, Hildreth BF [1979]. Paroxysmal atrial fibrillation and exposure to smoke. Lancet, May 12, p. 1036.

Blevins JS, Bounds R, Armstrong E, Coast JR [2006]. Health and fitness programming for fire fighters: does it produce results? Med Sci Sports Exerc *38*(5):S454.

Blumenthal RS, Epstein AE, Kerber RE [2007]. Expert Panel Recommendations: Cardiovascular disease and commercial motor vehicle safety (expedited review). [http://www.mrb.fmcsa.dot.gov/documents/CVD_Commentary.pdf] Accessed on September 21, 2007.

Bolstad-Johnson MD, Burgess JL, Crutchfield CD, Storment S, Gerkin R, Wilson JR [2000]. Characterization of firefighter exposures during fire overhaul. Am Ind Hyg Assoc J *61*:636-641.

Brandt-Rauf PW, Fallon LF Jr, Tarantini T, Idema C, Andrews L [1988]. The health hazards of fire fighters: exposure assessment. Br J Ind Med *45*:606-612.

Carter J [2001]. Use of self-contained breathing apparatus during overhaul. Fire Nuggets. [http://www.firenuggets.com/x_ARDSIllIIllllIIIllIlIIIIlllIllIl/carter6.htm] Accessed on: February 21, 2008.

CDC (Centers for Disease Control and Prevention) [2008]. BMI – Body Mass Index. [http://www.cdc.gov/nccdphp/dnpa/bmi/adult_BMI/english_bmi_calculator/bmi_calculator.htm]. Date accessed May 16, 2008.

Cook S [2006]. SCBA SOGs. FireRescue1. [http://www.firerescue1.com/Columnists/Scott-Cook/articles/103162/]. Accessed on: February 21, 2008.

DeBias D, Banerjee CM, Birkhead NC, Greene CH, Scott SD, Harrer WV [1976]. Effects of carbon monoxide inhalation on ventricular fibrillation. Arch Environ Health *31*:38-42.

Dempsey WL, Stevens SR, Snell CR [2002]. Changes in physical performance and medical measures following a mandatory firefighter wellness program. Med Sci Sports Exerc *34*(5):S258.

Fowler-Brown A, Pignone M, Pletcher M, Tice JA, Sutton SF, Lohr KN [2004]. Exercise tolerance testing to screen for coronary heart disease. A systematic review for technical support of the U.S. Preventive Services Task Force. Ann Intern Med *140*:W9-W-24.

Frost L, Hune LJ, Vestergaard P [2005]. Overwight and obesity as risk factors for atrial fibrillation or flutter: the Danish Diet, Cancer, and Health Study. Am J Med *118*:489-495.

Fuster V, Rydén LE, Cannom DS, et al. [2006]. ACC/AHA/ESC 2006 guidelines for the management of patients with atrial fibrillation—executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the European Society of Cardiology Committee for Practice Guidelines (Writing Committee to Revise the 2001 Guidelines for the Management of Patients With Atrial Fibrillation). Circulation

114:700-752. Available online at http://circ.ahajournals.org/cgi/reprint/114/7/700Accessed on: February 20, 2008.

Gibbons RJ, Balady GJ, Bricker JT, et al. [2002]. ACC/AHA 2002 guideline update for exercise testing: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation *106*:1883-1892.

Gronefeld GC, Mauss O, Li YG, et al. [2000]. Association between atrial fibrillation and appropriate implantable cardioverter defibrillation therapy: results from a prospective study. J Cardiovasc Electrophysiol *11*:1208-1214.

Hagens VE, Rienstra M, Van Veldhuisen DJ, Harry J.G.M. Crijns HJGM, Van Gelder IC [2006]. Determinants of sudden cardiac death in patients with persistent atrial fibrillation in the rate control versus electrical cardioversion (RACE) study. Am J Card *98*:929–932.

Hales T, Jackson S, Baldwin T [2007a]. NIOSH Alert: Preventing Fire Fighter Fatalities Due to Heart Attacks and Other Sudden Cardiovascular Events. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health Publication No. 2007-133 [http://www.cdc.gov/niosh/docs/2007-133/]. Date accessed: April 24, 2008.

Hales T [2007b]. Personal communication on May 1, 2006 between K. Varone, Providence Fire Department and T. Hales, Division of Surveillance, Hazard Evaluations, and Field Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Department of Health and Human Services.

IAFF/ IAFC (International Association of Fire Fighters/International Association of Fire Chiefs) [2000]. The fire service joint labor management wellness/fitness initiative. Washington, D.C.

IOM (Institute of Medicine) [2005]. Integrating Employee Health: A Model Program for NASA. National Academy Press, Washington, DC.

Jankovic J, Jones W, Burkhart J, Noonan G [1991]. Environmental study of firefighters. Ann Occup Hyg *35*:581-602.

Kales SN, Soteriades ES, Christoudias SG, Christiani DC [2003]. Firefighters and on-duty deaths from coronary heart disease: a case control study. Environ health: a global access science source. *2*:14. [http://www.ehjournal.net/content/2/1/14]. Date accessed: February 15, 2007.

Kales SN, Soteriades ES, Christophi CA, Christiani DC [2007]. Emergency duties and deaths from heart disease among fire fighters in the United States. N Eng J Med *356*:1207-1215.

Kinnes GM, Hine GA [1998]. Bureau of Alcohol, Tobacco, and Firearms, Washington, D.C. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. [http://www2a.cdc.gov/hhe/select.asp?PjtName=16432&bFlag=3]. Accessed on: February 19, 2008.

Kuehl K [2007]. Economic Impact of the Wellness Fitness Initiative. Presentation at the

2007 John P. Redmond Symposium in Chicago, IL on October 23, 2007.

Lauer M, Froelicher S, Williams M, Kligfield P [2005]. Exercise testing in asymptomatic adults. A statement from professionals from the American Heart Association council of clinical cardiology, subcommittee on exercise, cardiac rehabilitation, and prevention. Circulation *112*:771-776

Levy S, Maarek M, Coumel P, et al. [1999]. Characterization of the different subsets of atrial fibrillation in general practice in France: The ALFA study. The College of French Cardiologists. Circulation *99*:2455-2461

Maniscalco P, Lane R, Welke M, Mitchell J, Husting L [1999]. Decreased rate of back injuries through a wellness program for offshore petroleum employees. J Occup Environ Med *41*:813-820.

Marius-Nunez AL [1990]. Myocardial infarction with normal coronary arteries after acute exposure to carbon monoxide. Chest *97*:491-494.

Mittleman MA, Maclure M, Tofler GH, et al. [1993]. Triggering of acute myocardial infarction by heavy physical exertion. N Eng J Med *329*:1677-1683.

NFPA (National Fire Protection Association) [2007a]. NFPA 1582: Standard on Comprehensive Occupational Medicine Program for Fire Departments. Quincy, MA.

NFPA (National Fire Protection Association) [2007b]. NFPA 1500: Standard on Fire Department Occupational Safety and Health Program. Quincy, MA.

NFPA (National Fire Protection Association) [2008]. NFPA 1583: Standard on Health-Related Fitness Programs for Fire Department Members. Quincy, MA.

NHLBI - National Heart Lung Blood Institute [2008a]. Obesity education initiative. [http://www.nhlbi.nih.gov/health/public/heart/obesity/lose_wt/risk.htm#limitations]. Accessed on: February 20, 2008.

NHLBI - National Heart Lung Blood Institute [2008b]. Risk Assessment Tool for Estimating 10-year Risk of Developing Hard CHD (Myocardial Infarction and Coronary Death). [http://hp2010.nhlbihin.net/atpiii/calculator.asp?usertype=prof]. Accessed on: February 20, 2008.

NIOSH [2004]. Overtime and Extended Work Shifts: Recent Findings on Illnesses, Injuries, and Health Behaviors. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. [http://www.cdc.gov/niosh/docs/2004-143/pdfs/2004-143.pdf]. Accessed on: February 19, 2008.

Oral H, Pappone C, Chugh A, et al. [2006]. Circumferential pulmonary–vein ablation of chronic atrial fibrillation. N Eng J Med *354*:934-941.

Pedersen OD, Abildstrom SZ, Ottesen MM, et al. [2006]. Increase risk of sudden and non-sudden cardiovascular death in patients with atrial fibrillation/flutter following acute myocardial infarction. Eur Heart J *27*:290-295.

Phillips LH, Whisnant JP, Reagan TJ [1977]. Sudden death from stroke. Stroke *8*:392-395.

Sheps DS, Herbst MC, Hinderliter AL, Adams KF, Ekelund LG, O'Neil JJ, Goldstein GM, Bromberg PA, Dalton JL, Ballenger MN, Davis SM, Koch GG [1990]. Production of arrhythmias by elevated carboxyhemoglobin in patients with coronary artery disease. Ann Intern Med *113*:343-351.

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med *42*:1148-1155.

Stevens SR, Dempsey WL, Snell CR [2002]. The reduction of occupational absenteeism following two years of fire figher wellness. Med Sci Sports Exerc 34 (5): S194

Tofler GH, Muller JE, Stone PH, et al. [1992]. Modifiers of timing and possible triggers of acute myocardial infarction in the Thrombolysis in Myocardial Infarction Phase II (TIMI II) Stiudy Group. J Am Coll Cardiol *20*:1049-1055.

United States Fire Administration (USFA) [2008]. Firefighter autopsy protocol. Emmitsburg, MD: Federal Emergency Management Agency.

Van Gelder ID, Crijns HJ, wan Gilst WH, et al. [1989]. Efficacy and safety of flecainide acetate in the maintenance of sinus rhythm after electrical cardioversion of chronic atrial fibrillation or atrial flutter. Am J Cardiol *64*:1317-1321.

Waktare JEP [2002]. Atrial fibrillation. Circulation 106:14-16. Available online at http://circ.ahajournals.org/cgi/reprint/106/1/14. Accessed on February 4, 2008.

Wang TJ, Parise H, Levy D, D'Agostin RB, Wolf PA, Vasan RS, Benjamin EJ [2004]. Obesity and the risk of new-onset atrial fibrillation. JAMA *291*:2851-2855.

Willich SN, Lewis M, Lowel H, et al. [1993]. Physical exertion as a trigger of acute myocardial infarction. N Eng J Med *329*:1684-1690.

Womack JW, Humbarger CD, Green JS, Crouse SF [2005]. Coronary artery disease risk factors in firefighters: effectiveness of a one-year voluntary health and wellness program. Med Sci Sports Exerc *37*(5):S385.

INVESTIGATOR INFORMATION

This investigation was conducted, and the report written by Thomas Hales, MD, MPH. Dr. Hales is the team leader of the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio.

Appendix A - PHYSICAL AGILITY TEST (Page 1 of 3)

PROCTORS	**LOCAL CONTACTS**
Names removed	"A" Shift
Trained proctor arranged by above named	"C" Shift

WHEN THE TEST IS SCHEDULED

Assign an engine company to standby during the test

Assign a proctor from the list

Notify Local (see list) they can send an observer if desired

IMMEDIATELY BEFORE TEST IS ADMINISTERED

Go over course to make sure everything is in order including timer and time card

Make sure that test taker is familiar with the course

Take vital signs just prior to the start and then again five minutes after completion

Have test taker suit up and confirm that they are wearing a turnout coat with liner, fire department issued gloves and a 1 hour SCBA with at least 4000 lbs of air.

After Working Three Consecutive 24-Hour Shifts and Fighting an Extensive Structure Fire, a 47-Year Old Career LT Suffers Sudden Cardiac Death during Physical Fitness Training – California

Appendix A (page 2)
THE TEST (The employee taking the test is to complete the bulleted items below)
Start-Punch the timecard

- Walk around the central cone then to the Ladder Carry

Ladder Carry

- Remove 16 foot ladder from brackets mounted on the wall prop
- Carry the ladder around the cone placed 20 feet from the wall

notes: 1. The first time the ladder hits the ground give a warning
2. The second time the ladder hits the ground, stop the test. Disqualification

- Replace the ladder on the brackets
- Walk back around the central cone to the Hose Drag

Hose Drag (Please note: This is the only time the test taker can run)

- Wrap one end of the hose over shoulder and across chest
- Drag the hose to the other side of the event, 200 feet away
- Cross the first white line, drop end of hose and drag the remainder across the line using a "hand over hand" or a "pick up and pull" technique
- Do not cross the second white line, it is 10 feet beyond the first

notes: 1. Assist by flaking out hose behind the second white line
2. The first time the second white line is crossed give a warning
3. The second time the line is crossed, stop the test. Disqualification

- After the entire hose is behind the first white line, walk back around the central cone, around the cone near the Ladder Carry, then proceed to the Hose Pack Carry

Hose Pack Carry

- Pick up the bundle of hose and carry it to the fourth floor of the tower using each step

note: Every step must be touched

- On the fourth floor, drop the hose in the marked space and go to the Hose Hoist window

Hose Hoist

- At the window, grab the rope and pull up the hose bundle
- Raise the hose with a hand over hand motion on the rope, until it reaches the window
- Place hose bundle on the window sill
- Step back, then lower the hose to the ground with a hand over hand motion on the rope

notes: 1. The first time one steps outside the 4x4 foot box, give a warning
2. The second time one steps out of the box, stop the test. Disqualification
3. When lowering hose, rope cannot slide through the hands. If so, rope must be raised to the point at which it began to slide, then lowered.

- Pick up the bundle, carry it downstairs using every step, and return it to its original position
- Walk to the Attic Crawl

Appendix A (page 3)

Attic Crawl
- Walk or crawl through the simulated attic without touching the ground

note: If ground is touched, employee must go back to the missed joist
- Walk to the Dummy Drag

Dummy Drag
- Drag the dummy through the 20 foot tunnel
- At the end of the tunnel turn the dummy around so that it faces the opposite direction
- Walk around the two cones for a cool down period
- Walk to the Four Foot Wall

Four Foot Wall
- Scale the four foot wall

note: One may not run to the wall or use the braces on either side as a step
- Walk to the Hose Roll

Hose Roll
- Roll one 50 foot length of hose in one direction
- Roll second length of hose in the opposite direction
- Walk to the Tailgate Hose Load

note: Proctor should unroll each length of hose if there will be subsequent test takers

Tailgate Hose Load
- Load the six rolls of hose onto the tailboard, one at a time
- Walk behind the starting line, empty handed
- Return to tailgate and stack each roll in the starting box, one at a time

Finish
- Take final cool down walk
- Walk around remaining cones on course and then to finish line

note: Punch timecard

(Passing score is completion in 14 minutes and 55 seconds).