



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

SUMMARY

On June 26, 2008, the Deputy Fire Chief reported to duty at 0800 hours. About three hours later he performed a fire prevention inspection of a local apartment building. Before returning to headquarters he stopped by one of the fire stations to visit with fellow fire fighters. While sitting at the kitchen table, the Deputy Chief collapsed. Despite immediate advance life support measures in the fire station, ambulance, and hospital emergency department, the Deputy Chief died. An autopsy performed by a forensic pathologist in the Office of the County Coroner concluded “left ventricular cardiac hypertrophy (years)” was the cause of death. The NIOSH investigator concluded that the Deputy Chief’s sudden cardiac death was most likely due to a heart arrhythmia associated with high blood pressure, left ventricular hypertrophy, and an enlarged heart; a conclusion consistent with the County Coroner’s autopsy report. The evidence does not suggest that the fire prevention inspection conducted by the Deputy Chief about an hour before his cardiac arrest triggered his heart arrhythmia.

The NIOSH investigator offers the following recommendations to reduce the risk of on-duty heart attacks and sudden cardiac deaths in this and other fire departments across the country. It is unlikely, however, that these recommenda-

tions could have prevented the Deputy Chief’s sudden cardiac death.

- Ensure all uniformed members of the Fire Protection District receive annual medical and fitness evaluations.
- Limit the number of consecutive shifts a fire fighter can work.

INTRODUCTION & METHODS

On June 26, 2008, a 44-year-old male, career Deputy Fire Chief suffered sudden cardiac death while on-duty. On June 30, 2008 NIOSH was notified of this fatality by the United States Fire Administration. On July 8, 2008 NIOSH contacted the Fire Protection District to gather additional information about the death. On September 3, 2008, an occupational medicine physician from the NIOSH Fire Fighter Fatality Investigation and Prevention Program traveled to the Fire Protection District to conduct an on-site investigation of the incident.

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

- Acting Fire Chief
- Vice-President of the local chapter of the



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

International Association of Fire Fighters

- “B Shift” crew members on-duty with the Deputy Chief
- Investigator from the County Coroner’s office
- Forensic pathologist who conducted the autopsy
- Fitness instructor overseeing the Fire Protection District’s fitness program

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

- Fire Protection District incident response form
- Ambulance response form
- Autopsy report
- Deputy Chief’s medical records maintained by the Fire Protection District
- Deputy Chief’s fitness evaluation records maintained by the fitness instructor
- Components of the Fire Protection District’s medical evaluation program
- Components of the Fire Protection District’s wellness-fitness program

INVESTIGATIVE RESULTS

Incident. At 0800 hours on June 26, 2008 the Deputy Fire Chief reported to headquarters (Station 9) to begin the first day of his 48-hour shift. Since April 2008, the Deputy Chief was

not only serving as the Deputy Fire Chief, but he was also filling a vacancy as the B Shift Battalion Chief. He was also a Fire Marshal for the Fire Protection District. The day began with a meeting on various fire prevention responsibilities with the Acting Fire Chief. This meeting lasted about an hour, followed by about an hour and a half of administrative duties at headquarters.

At approximately 1030 hours the Deputy Chief left headquarters to conduct a fire prevention inspection of a local apartment building. These inspections typically consist of checking the sprinkler system associated with new or remodeling construction with sprinklers, or, once the construction is completed, ensuring the system is adequately pressurized. According to the Acting Fire Chief, the inspection process did not involve vigorous physical activity. The inspection lasted approximately 30 minutes and once completed, the Deputy Chief checked-in with fire fighters at the nearby fire station (Station 2).

Station 2 was comprised of an engine crew (E-1) and an ambulance crew (M-31). E-1 was staffed by a lieutenant, a fire fighter/engineer, and a fire fighter/paramedic. M-31 was staffed by two employees: a fire fighter/paramedic and a fire fighter/emergency medical technician (EMT). The Deputy Chief arrived at Station 2 at approximately 1140 hours. Shortly thereafter Station 2’s engine crew responded to an emergency call. The ambulance crew, however, remained in the station with the Deputy Chief. The Deputy Chief and M-31’s crew conversed about various work tasks and local sporting news.



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

At 1224 hours, while talking at Station 2's kitchen table, the Deputy Chief became unresponsive and then immediately began having seizure activity described as tonic-clonic movement of his upper extremities. The fire fighter/paramedic moved the Deputy Chief from his chair to the floor and notified dispatch by radio. He then went downstairs to retrieve the cardiac monitor, intubation kit, oxygen, and advanced life support bag from the ambulance. He returned upstairs to find the Deputy Chief no longer having seizure activity, but still unresponsive. Vital signs revealed the Deputy Chief no longer had spontaneous respirations or a pulse. The fire fighter/paramedic applied the cardiac pads to the Deputy Chief's chest and the cardiac monitor showed ventricular fibrillation. A shock of 120 joules was delivered at 1226 hours changing the Deputy Chief's heart rhythm to pulseless electrical activity. Cardiopulmonary resuscitation (CPR) was begun by the M-31's fire fighter/EMT as the fire fighter/paramedic informed dispatch that the incident was now a full cardiac arrest occurring in a member of the Fire Protection District.

The fire fighter/paramedic prepared to intubate the Deputy Chief, however, as he initiated the procedure the Deputy Chief's heart rhythm converted back into ventricular fibrillation and the intubation procedure was aborted. A 150 joule shock was delivered at 1228 hours, but, again, the Deputy Chief's heart rhythm converted into pulseless electrical activity. Oxygen was administered by bag-mask-valve and CPR was reinitiated. At this time E-1 had just returned to the station and crew members assisted with lifting the Deputy Chief onto a

stretcher and carrying him down the Station 2's stairs (1231 hours). At the bottom of the stairs the Deputy Chief was shocked again at 200 joules changing the Deputy Chief's heart rhythm to asystole. The dispatched ambulance from Station 4 (M-33) had arrived at Station 2 at 1233 hours. The Deputy Chief was loaded into the back of M-33 which departed for the local emergency department at approximately 1234 hours.

En route to the hospital's emergency department, three fire fighter/paramedics from M-33, M-31, and E-1 and one fire fighter/EMT provided advanced life support. The fire fighter/paramedics were unable to place an intravenous line, thereby necessitating the administration of medications (three doses of epinephrine, and two doses of atropine) by the intraosseous route. Endotracheal intubation was initiated, but given the difficulty visualizing the Deputy Chief's vocal cords, the decision was made to continue oxygen administration with a Combitube®. Proper placement of the Combitube® was confirmed by both an esophageal detector tube and CO2 measurement as recommended by the American Heart Association [AHA 2005]. One additional shock was administered at 1243 hours with no change in the Deputy Chief's clinical status. M-33 arrived at the hospital's emergency department at 1248 hours. Advanced life support continued for approximately 25 minutes when the Deputy Chief was pronounced dead and resuscitation efforts were discontinued.

Medical Findings. A forensic pathologist from the County Coroner's office completed the au-



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

topsy report and concluded that “left ventricular cardiac hypertrophy (years)” was the cause of death. Pertinent findings from the autopsy included the following:

- Mild arteriosclerosis of the coronary arteries
- An enlarged heart of 555 grams with concentric left ventricular hypertrophy
- No blood clots in the pulmonary arteries (e.g., no pulmonary embolus)
- No evidence of a bleed into the brain (e.g., stroke)
- Negative blood testing for alcohol or illicit drugs

No sections of the heart were taken for microscopic examination.

Since at least 2001, the Deputy Chief had intermittent elevated blood pressure readings but was never diagnosed with hypertension or treated with anti-hypertensive prescription medications. He was overweight/obese with body mass index ranging from 30 to 34 from 2001 to 2007 [CDC 2008]. As part of the Fire Protection District’s medical evaluation program, the Deputy Chief underwent exercise treadmill tests in 2001, 2004, and 2006. Despite having left ventricular hypertrophy confirmed at autopsy, none of his resting electrocardiogram (EKG) results met the voltage criteria for a diagnosis of left ventricular hypertrophy. Results from his most recent exercise treadmill test in 2006 demonstrated good aerobic capacity; he exercised for 12 minutes under the Bruce protocol reaching

12.9 metabolic equivalents (METs). The test was stopped because he had reached his target heart rate, MET requirements, and had appropriate fatigue. He had no chest pain, no unusual shortness of breath, and a normal blood pressure response. He had no EKG changes suggestive of ischemia, although he did have a single ectopic ventricular contraction and two ectopic ventricular contractions together (couplet) at peak exercise. Ectopic ventricular beats are only of concern in subjects with a family history of sudden death, or a personal history of cardiomyopathy, valvular heart disease, or severe myocardial ischemia [Kennedy et al. 1985; Fletcher et al. 2001]. The Deputy Chief had none of these risk factors. In 2001, 2004, and 2006, the exercise treadmill tests were considered negative and the Deputy Chief was cleared for full duty. The Deputy Chief never reported symptoms suggestive of heart disease to coworkers, or while performing fire fighter duties.

DESCRIPTION OF THE FIRE PROTECTION DISTRICT

At the time of the NIOSH investigation, the Fire Protection District consisted of 51 uniformed personnel and served a population of 28,000 residents in a geographic area of 11.5 square miles. The department has three fire stations, each equipped with an engine and an ambulance/rescue vehicle. Engines are staffed with three personnel (an officer, an engineer, and a fire fighter/paramedic), while the ambulance/rescue vehicles are staffed with two personnel (a fire fighter/paramedic and a fire fighter/



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

EMT). Fire fighters work 48 hour shifts (0800 to 0800 hours), and are off duty for 96 hours. There are no restrictions on the number of consecutive shifts that can be worked.

Hiring Procedure. Applicants for the position of fire fighter are required to complete an application. Applicants must hold a California drivers license, be National Fire Protection Association (NFPA) certified fire fighters (FF-1), and be a certified EMT-1. Applicants then take a Fire Protection District physical ability test or the Candidate Physical Ability Test (CPAT) [IAFF/IAFC 2000]. Those passing the physical ability test, or those who had passed the CPAT in the previous year, then take the written examination. Applicants passing the written examinations are interviewed and ranked by members of the Fire Protection District. The top 10 candidates are then re-interviewed by four senior Captains of the Fire Protection District. The top two or three candidates have background checks, a psychological evaluation, a medical evaluation, and a drug screen. If the candidate passes these evaluations he/she is hired as a probationary employee for 1½ years.

The Deputy Chief had 20 years of fire experience, 14 of those years as a full-time fire fighter with this Fire Protection District. He was certified as Fire Fighter I & II, Fire Officer, apparatus operator, hazmat responder at level I & II, wildland fire fighter I-IV, fire service instructor, and EMT.

Pre-employment/Pre-placement Medical Evaluations. The Fire Protection District re-

quires a pre-employment/pre-placement medical evaluation for all new hires, regardless of age. Components of this evaluation for all applicants include the following:

- A complete medical history (including respiratory questionnaire for respirator medical clearance)
- Height, weight, and vital signs
- Physical examination
- Titmus vision screen
- Audiogram
- Spirometry
- Chest X-ray (two views)
- Tuberculin skin test
- Blood tests (complete blood count, chemistry 20 panel, lipid panel, iron)
- Urinalysis
- Resting EKG
- Exercise treadmill test
- Serology (hepatitis A, B, and C titers)
- Immunizations as needed (e.g., flu vaccine, hepatitis B vaccine, tetanus, rubella, rubeola, varicella, mumps)
- Urine drug test for illicit drug use
- Prostate screen for men 50 years or older

These evaluations are performed by a health care organization under contract with the city. Once the evaluation is complete, a physician makes a decision regarding medical clearance for fire fighting duties which is eventually forwarded to the personnel department. The



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

Deputy Chief was cleared for duty during his candidate medical evaluation in 1994.

Periodic Medical Evaluations. Since 2001, the Fire Protection District has required annual medical evaluations of all members. The evaluations are performed by one health care organization and the components of this evaluation are the same as the candidate medical evaluation (listed above) with the exception of the following 1) no chest X-ray unless indicated by symptoms, 2) no serology testing unless indicated by exposures, 3) no urine drug test, and 4) no resting EKG or exercise treadmill test unless indicated by symptoms or by age and number of coronary artery disease (CAD) risk factors. The Deputy Chief had annual medical evaluations conducted every year beginning 2001, but missed his evaluations in 2003 and 2007.

Fitness and Wellness Programs. The Fire Protection District has a wellness and fitness program modeled after the IAFF/IAFC wellness-fitness initiative [IAFF/IAFC 2008]. The fitness portion of the program is overseen by the fitness instructor employed by the city. Each station has exercise equipment donated from local health clubs. The instructor conducts annual fitness assessments of the member's strength, flexibility, and aerobic capacity. Individualized "training for improvement plans" are developed using results from the fitness assessment. There are no fitness standards, but participation is mandatory. The Deputy Chief regularly participated in the fitness assessments and followed his exercise plan. For unclear reasons, however, he missed his 2007 fitness assessment.

If a member suffers a work related injury or illness, they must be evaluated by a pre-designated primary care physician of their choice. This physician provides an opinion for return-to-duty which is forwarded to the Fire Protection District's contracted health care organization. If a member misses four shifts due to a non-work related injury or illness, they must be cleared for return to duty by the same health care organization.

DISCUSSION

Cardiac Arrest and Sudden Cardiac Death.

The Deputy Chief experienced a cardiac arrest and sudden cardiac death about 1 hour after conducting a fire prevention inspection. The most common risk factor for cardiac arrest and sudden cardiac death is CAD, defined as the build-up of atherosclerotic plaque in the coronary arteries [AHA 2008]. The autopsy report, however, found only mild CAD and no evidence of an acute heart attack. Therefore, the most likely reason for the Deputy Chief's sudden cardiac death was a heart arrhythmia. Fire fighters are at increase risk for of sudden cardiac events during fire suppression, training, alarm response, and strenuous physical activity on the job [Kales et al. 2003, 2007; Hales et al. 2007]. The evidence does not suggest that the fire prevention inspection conducted by the Deputy Chief about an hour before his cardiac arrest constituted strenuous physical activity.

Left Ventricular Hypertrophy and Heart Enlargement. On autopsy, the Deputy Chief had left ventricular hypertrophy which was respon-



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

sible for his enlarged heart. Hypertrophy of the heart's left ventricle is a relatively common finding among individuals with long-standing high blood pressure (hypertension), a heart valve problem, chronic cardiac ischemia due to CAD, or, less commonly, hypertrophic cardiomyopathy. On autopsy, the Deputy had normal heart valves, mild CAD, and "concentric" hypertrophy localized to the left ventricle, findings that strongly suggest his elevated blood pressure was responsible for his left ventricular hypertrophy [Maron 2005; Hughes 2004].

Under-diagnosed, un-treated, and under-treated hypertension is a problem in the United States. Approximately 30% of adults are unaware of their high blood pressures, 40% of individuals with hypertension were not on treatment, and 66% of hypertensive patients are not controlled to BP levels less than 140/90 [Chobanian et al. 2003]. Poorly controlled hypertension markedly increases the risk for heart disease, strokes, and renal disease. The fire service is not spared this disease or problem. Approximately 20% of fire fighters have hypertension and an additional 20% have prehypertension [Soteriades et al. 2003; 2005]. In 2003, the Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure updated their classification of, and treatment guidelines for hypertension [Chobanian et al. 2003]. The FD and their contract medical services may want to review these guidelines.

The Deputy Chief had resting EKGs taken in 2001, 2004, and 2006, yet none of these tracings met the voltage criteria for left ventricular

hypertrophy. The sensitivity of an EKG correctly identifying left ventricular hypertrophy in an obese, young (less than 50 years old) man is less than 5% [Levy et al. 1990; Okin et al. 2002]. The NIOSH Fire Fighter Fatality Investigation and Prevention Program notes that many fire fighters suffering sudden cardiac death have left ventricular hypertrophy at autopsy yet their resting EKGs have not detected this condition. Additional research is needed to assess whether the voltage criteria for left ventricular hypertrophy need to be revised, or whether echocardiograms are a more appropriate screening test for left ventricular hypertrophy in fire fighters with long-standing hypertension.

Hypertension, left ventricular hypertrophy, and cardiomegaly all increase the risk of sudden cardiac death [Haider et al. 1998; Verdecchia et al. 1998; Bigger et al. 1994]. Therefore, NIOSH investigators consider that the Deputy Chief's sudden cardiac death was most likely due to a heart arrhythmia associated with high blood pressure, left ventricular hypertrophy, and an enlarged heart. This conclusion is consistent with the County Coroner's autopsy report. The evidence does not suggest that the fire prevention inspection conducted by the Deputy Chief about an hour before his cardiac arrest triggered his heart arrhythmia.

Screening Tests for Cardiac Disease—Exercise Treadmill Tests. Exercise treadmill tests can screen for CAD and provide valuable prognostic information, however testing asymptomatic individuals is controversial. The National Fire Protection Association (NFPA) 1582 states,



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

“Stress EKG with or without echocardiogram or radionuclide scanning shall be performed as clinically indicated by history or symptoms” and refers the reader to Appendix A [NFPA 2007]. Items in Appendix A are not standard requirements, but are provided for “informational purposes only.” Appendix A recommends that sub-maximal (85% of predicted heart rate) stress tests be used as a screening tool to evaluate a fire fighter’s aerobic capacity. Maximal (e.g., symptom limiting) stress tests with imaging should be used for fire fighters with the following risk factors:

- abnormal screening sub-maximal tests
- cardiac symptoms
- known coronary artery disease
- Males over the age of 45 and females over the age of 55 with two or more risk factors for coronary artery disease. Risk factors are defined as 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 coronary artery disease (heart attack or sudden cardiac death in a first-degree relative less than 60 years old).

The American College of Cardiology / American Heart Association (ACC/AHA) has also published exercise testing guidelines [Gibbons et al. 2002]. The ACC/AHA states that the evidence to conduct stress tests in asymptomatic individuals with diabetes mellitus is “Class IIa” which is defined as “conflicting evidence

and/or a divergence of opinion about the usefulness/efficacy but the weight of the evidence/opinion is in favor.” The ACC/AHA goes 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 coronary artery disease due to other diseases (e.g., peripheral vascular disease and chronic renal failure)

The U.S. Department of Transportation has also provided guidance for those seeking medical certification for a commercial drivers license. Their expert medical panel recommended exercise tolerance tests for asymptomatic “high risk” drivers [Blumenthal et al. 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



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

- Framingham risk score predicting a 20% coronary heart disease event risk over the next 10 years

The U.S. Preventive Services Task Force (USPSTF) does not recommend stress tests for asymptomatic individuals at low risk for coronary heart disease events. For individuals at increased risk for coronary heart disease events, they found “insufficient evidence to recommend for or against routine screening with EKG, exercise tolerance test, or electron beam computerized tomography scanning...” Rather, they recommend the diagnosis and treatment of modifiable risk factors (hypertension, high cholesterol, smoking, and diabetes) [USPSTF 2004]. The USPSTF does note that “For people in certain occupations, such as pilots, and heavy equipment operators (for whom sudden incapacitation or sudden death may endanger the safety of others), consideration other than the health benefit to the individual patient may influence the decision to screen for coronary heart disease.”

Currently the Fire Protection District is conducting exercise treadmill tests based on age and the number of CAD risk factors. This has resulted in exercise treadmill tests being conducted on younger members and more frequently than recommended by the 2007 edition of the NFPA 1582 [NFPA 2007]. However, given the varying recommendations for when to conduct exercise treadmill tests for jobs that impact public safety, the current program is reasonable. We recommend the Fire Protection District, in conjunction with their contracted health care organization, continue to monitor developments on this topic.

RECOMMENDATIONS

The NIOSH investigator offers the following recommendations to reduce the risk of on-duty heart attacks and sudden cardiac deaths in this and other fire departments across the country. It is unlikely, however, that these recommendations could have prevented the Deputy Chief’s sudden cardiac death.

Recommendation #1. Ensure all uniformed members of the Fire Protection District receive annual medical and fitness evaluations.

The NIOSH investigator applauds the Fire Protection District and the local union for developing and implementing a comprehensive wellness-fitness and medical evaluation program. A program’s success, however, is affected by lack of participation. The Deputy Chief missed two of his last seven medical evaluations, and his last fitness assessment. While this was probably due to a heavy workload from multiple assignments, it demonstrates the need for the Fire Protection District to assign someone to administer the programs to ensure accountability.

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

In 2004, NIOSH reviewed the research 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 in-



Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

creased 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 et al. 2005; Barger et al. 2006].

Currently, the Fire Protection District works 48 hours followed by 96 hours off. However, fire fighters are allowed to exchange shifts, thereby setting up the possibility that a fire fighter may be on duty for up to 96 hours. While District fire fighters frequently get some sleep during their work shifts, this sleep can be interrupted by the numerous ambulance calls that are made during the night and early morning hours. Although there are no data linking chronic sleep deprivation with sudden cardiac death, 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 and the public.

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Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

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Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

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INVESTIGATOR INFORMATION

This investigation was conducted by and the report written by:

Thomas R. Hales, MD, MPH

Senior Medical Epidemiologist

Dr. Hales is with the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Dr. Hales is board certified in Internal Medicine and Occupational Medicine, and is a member of NFPA Technical Committee Fire Service Occupational Safety and Health.



NIOSH
Fire Fighter Fatality Investigation
and Prevention Program

Fatality Assessment and Control Evaluation
Investigation Report • F2008-31

Deputy Fire Chief Suffers Sudden Cardiac Arrest About One Hour After Conducting a Fire Prevention Inspection - California.

The National Institute for Occupational Safety and Health (NIOSH), an institute within the Centers for Disease Control and Prevention (CDC), is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. In fiscal year 1998, the Congress appropriated funds to NIOSH to conduct a fire fighter initiative. NIOSH initiated the Fire Fighter Fatality Investigation and Prevention Program to examine deaths of fire fighters in the line of duty so that fire departments, fire fighters, fire service organizations, safety experts and researchers could learn from these incidents. The primary goal of these investigations is for NIOSH to make recommendations to prevent similar occurrences. These NIOSH investigations are intended to reduce or prevent future fire fighter deaths and are completely separate from the rulemaking, enforcement and inspection activities of any other federal or state agency. Under its program, NIOSH investigators interview persons with knowledge of the incident and review available records to develop a description of the conditions and circumstances leading to the deaths in order to provide a context for the agency's recommendations. The NIOSH summary of these conditions and circumstances in its reports is not intended as a legal statement of facts. This summary, as well as the conclusions and recommendations made by NIOSH, should not be used for the purpose of litigation or the adjudication of any claim. For further information, visit the program website at

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