2012
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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *January, 2015*

Captain Suffers Sudden Cardiac Death During Physical Fitness Training – California

Executive Summary

On April 3, 2012, a 50-year-old male career fire captain (the Captain) was working an 8-hour overtime shift at a remote fire camp. Soon after arriving at the camp, the Captain participated in a morning physical training hike with his crew. The Captain was assigned the "sweeper" position during the hike. At the 1.4-mile point, one crewmember was lagging behind and the Captain advised him to walk faster to finish the hike on time. Approximately 35 minutes later, the crew became aware that the Captain had not yet returned to camp and a search party was assembled. Approximately 23 minutes later, the crew found the Captain unconscious along the trail. Dispatch was notified and a helicopter, an engine, and an advanced life support squad were sent to the scene. Despite cardiopulmonary resuscitation and advanced life support on the scene, in transport, and at the hospital's emergency department (ED), the Captain died at 1220 hours. The autopsy revealed "coronary atherosclerosis," but "no acute intraluminal coronary thrombus" suggesting an acute heart attack did not occur and normal vitreous chemistries suggesting the Captain was not dehydrated. The coroner's office attributed the cause of death to "atherosclerotic heart disease." Given the Captain's underlying coronary heart disease (CHD) disease, NIOSH investigators concluded that the physical stress of the physical fitness training probably triggered a primary cardiac arrhythmia causing his sudden cardiac death.

NIOSH investigators offer the following recommendations, although it unclear if this recommendation would have prevented the Captain's death.

Review County policies regarding work restrictions for fire fighters with coronary heart disease identified by various screening tests and risk assessment models/databases.

The following recommendations would not have prevented the Captain's death, but are offered to strengthen the already impressive FD safety and health program.

Provide annual medical evaluations to ALL fire fighters consistent with NFPA 1582 or the IAFF/IAFC Wellness Fitness Initiative.

Perform an annual physical performance (physical ability) evaluation for all members.

Discontinue exercise stress tests on asymptomatic fire fighters who are at low risk for coronary heart disease (CHD).

Discontinue routine screening chest x-rays for members, unless clinically indicated.

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Introduction & Methods

On April 3, 2012, a 50-year-old male career captain died during physical fitness training. NIOSH contacted the affected Fire Department (FD) on April 5, 2012, to gather information, and again on April 6, 2012, to initiate the investigation. On May 7, 2012, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- FD Safety Officer
- FD Division Chief for Risk Management
- FD State Occupational Safety and Health Administration Compliance Coordinator
- Union Second Vice-President
- Crewmembers
- Captain's spouse
- Physicians with the County Occupational Health Program

NIOSH personnel reviewed the following documents:

- FD standard operating procedures
- FD annual report for 2011
- FD incident report
- Emergency medical service (ambulance) report
- Hospital ED report
- Autopsy
- FD medical evaluation records

Results of Investigation

Incident. On April 3, 2012, the Captain reported for an 8-hour overtime shift at 0815 hours. The Captain was part of a five-person supervisory crew (foremen) at a remote fire camp (Camp 14). The camp was part of the State Department of Corrections system that provides inmates to fight wildland fires. The State has 978 inmate fire fighters assigned to 68 inmate fire crews working in 44 inmate camps. Camp 14 was comprised of 90 inmate fire fighters of whom about 55 participated in the training on April 3, 2012.

The five foremen met at 0820 hours to discuss the day's activities including individual responsibilities and the inmate fitness hike. The Captain commented that he was nauseated due to a colonoscopy conducted the previous day and some crewmembers reported observing the Captain vomiting that morning [Hales 2013]. Due to these symptoms, the Captain requested the "sweeper" position in case he needed to return to camp. Prior to the hike, each foreman retrieved a portable radio and 1 quart of water in a canteen.

At 0854 hours, the group began the fitness hike. Weather conditions included a temperature of 66 degrees Fahrenheit and 29% relative humidity [NOAA 2014]. The Captain wore Nomex® pants, a long sleeved shirt, and tennis shoes. The trail began just across the road from the camp's administration building and started with a 699-foot, 30-degree slope climb up a hill to a ridgeline (Photograph 1 and Photograph 2). The trail has about ¼ - ½ mile visibility and varies in width and terrain (Photographs 3-5). Crewmembers typically spread out during the hike due to their differing physical abilities and the narrow sections of the trail. (For a timeline of events, see Appendix A).

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Photograph 1: Base camp and hill.

Photograph 2: Steep hill.

Photograph 3: The trail.

Photograph 4: the trail at the top of the hill

Photograph 5: Narrow trail.

Photograph 6: Location where the Captain collapsed.

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Results of Investigation (cont.)

Apparently, the Captain had not performed a camp hike in 4 years. During the first 40 minutes of the hike, the Captain needed to rest on three separate occasions, typically resting for 2-6 minutes during each break. At 0945 hours, the Captain advised the inmate hiking with him to walk ahead of him to finish the hike within the allotted time. The inmate walked faster and left the Captain at a turn in the trail.

At 0952 hours the last inmate finished the hike, assuming the Captain returned to the camp by a different path. By 1020 hours, all crewmembers (except the Captain) were back in camp. Noting the Captain was absent, crewmembers searched the camp without success. At 1030 hours, a foreman and two inmates formed a search team and hiked up the hill to locate the Captain. Thinking the Captain might be suffering from dehydration, they brought along a trauma kit, water and Gatorade®, a portable radio, and snacks.

At 1055 hours, the foreman found the Captain face down on the trail about 75 yards from where he was last seen (Photograph 6). The foreman's initial assessment revealed that the Captain had no pulse or respirations. The foreman notified the supervisor and a helicopter was requested to remove the Captain from atop the hill.

At 1103 hours, Engine 156 (E156), Squad 111 (S111), and Copter 15 were dispatched; Battalion Chief 6 (BC6) was dispatched at 1104 hours. While units were en route to the scene, the on-scene crew members gathered equipment (hand tools, chainsaws) to carve out a landing zone at the top of the hill. BC 6 arrived on scene at 1104 hours, E156 and S111 arrived at 1121 hours, and Copter 15 arrived at 1122 hours.

Copter 15 dropped off a paramedic with a jump kit and then returned a few minutes later with two additional paramedics. When the cardiac monitor showed asystole (no heart beat), cardiopulmonary resuscitation was initiated. Advanced life support was initiated including intravenous line, oral airway placement, and cardiac resuscitation medications. Crewmembers carried the Captain to the landing zone and placed him inside Copter 15, which departed at 1154 hours en route to the nearest hospital's ED.

Copter 15 arrived at the hospital at 1205 hours. Inside the ED the cardiac monitor continued to show asystole as the Captain was intubated. Cardiopulmonary resuscitation and advanced life support efforts continued until 1220 hours, when the Captain was pronounced dead by the attending physician and resuscitation efforts were discontinued.

Medical Findings. The autopsy revealed "coronary atherosclerosis," but "no acute intraluminal coronary thrombus" suggesting an acute heart attack did not occur. Vitreous chemistries were normal suggesting the Captain was not dehydrated from the previous day's bowel preparation, vomiting, or the physical activity. The coroner's office attributed the cause of death to "atherosclerotic heart disease." See Appendix B for more detailed autopsy findings.

The Captain had a preplacement medical evaluation with the County in 1993 and was hired in 1994. At this time he was noted to have hyperlipidemia (high blood total cholesterol and triglycerides) which, over the ensuing 19 years, was poorly controlled with diet and exercise. The FD physician repeatedly recommended that the Captain follow-up with his private physician for further evaluation and treatment. Although a statin was recommended and prescribed, the Captain never started statin treatment.

Results of Investigation (cont.)

Through a variety of FD medical evaluation programs [HAZMAT, commercial driver's license, and fitness-for-life (discussed in a separate portion of this report)] the Captain received annual FD medical evaluations including annual exercise treadmill tests (ETT). From 1993 to 2010, the Captain's ETTs were consistently negative. He exercised to 95% of his target heart rate; had no angina, arrhythmias, or electrocardiogram (EKG) changes consistent with ischemia; and had a normal blood pressure response to exercise. However, in 2008, the cardiologist conducting the test called the test "abnormal" due to 1 to 2 millimeter (mm) ST segment depression in the lateral and inferior leads. Per County Occupational Health Program protocol, the ETT tracings were reviewed by the academic/research center cardiologist who considered the test normal and no further work-up or work restrictions were recommended.

In 2011, the Captain's ETT, again, showed ST segment depression, determined to be abnormal by the academic/research center cardiologist. Per County protocol, a coronary artery calcium (CAC) scan was recommended. This test revealed 11 calcium lesions in the left anterior descending, circumflex, and right coronary arteries with a total coronary artery calcium score of 170. Again, per County protocol, these findings prompted the cardiologist to recommend a coronary computed tomography angiogram (CCTA), which found the following:

- Normal left main coronary artery
- 50% stenosis in the left anterior descending coronary artery
- Severe stenosis in the circumflex at the bifurcation of the circumflex marginal vessel
- Moderate mixed proximal and mid-vessel plaque in the right coronary artery, which is the dominant coronary artery
- Normally sized left ventricle and other cardiac structures.

The Captain was cleared for work with no restrictions by both the academic/research center cardiologist and by the County contract physician.

On February 15, 2012 (six weeks prior to his sudden cardiac death), the Captain underwent his routine FD annual evaluation. He was 71 inches tall and weighed 220 pounds, giving him a body mass index of 30.7 kilograms per meter squared [CDC 2014]. His blood pressure was 126/82 millimeters of mercury (mmHg), with a total cholesterol of 301 milligrams per deciliter (mg/dL), high density lipoprotein (HDL) of 35 mg/dL, low density lipoprotein (LDL) of 221 mg/dL, resulting in a Framingham risk score (FRS) (10-year heart disease risk) of 12% [NHLBI 2013]. The ETT was conducted using the Bruce protocol. The Captain exercised for 9 minutes 38 seconds (38 seconds into stage 4) when his maximal heart rate (169 beats per minute) was reached. He reported no angina, had a normal blood pressure response, and reached an estimated maximal oxygen consumption (VO2max) of 36.1 milliliters per kilogram per minute (ml/kg/min) or 10.3 metabolic equivalents (METs). The EKG tracing showed a 1.5 mm ST depression inferiorly and 1.0 mm laterally. These changes appeared at 5 minutes into exercise, peaked at 9 minutes, and recovered within 1 minute post-exercise. No arrhythmias were noted. The academic/research center cardiologist noted that the ETT was similar to the previous study in 2011, and, after reviewing the ancillary studies done in 2011, he did not recommend any further studies or work restrictions.

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Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of 171 fire stations with 2,818 career uniformed personnel serving 3.9 million residents in a geographic area of 2,305 square miles. In 2011, the FD responded to 297,304 incidents, including 7,549 fires, 216,576 medical calls, 34,049 false alarms, 2,558 mutual aid responses, 674 hazardous material calls, and 35,898 other calls.

Membership and Training. The FD requires new full-time fire fighter applicants to be 18 years of age, have a valid state driver's license, have a high school diploma or a General Equivalency Diploma (GED), and pass an eight-station candidate physical ability test (CPAT) (components are listed below). The successful applicant receives 1-year eligibility to be hired. When vacancies occur, a computer lottery randomly selects names for the written civil service exam. The successful applicant is then placed on an eligibility list. The applicant must pass a preplacement medical evaluation (described below), a background investigation, and an oral interview. After receiving a conditional job offer, the new hire is placed in the next 17-week Fire Academy to be trained to the Fire Fighter I level. The new hire is placed on probation for 1 year and works a 56-hour per week schedule (24 hours on-duty/24 hours off-duty, 24 hours on-duty/48 hours off-duty, 24 hours on-duty/4 days off-duty). The Captain was certified as a Fire Fighter I and II, Driver/Operator, Wildland Engine Boss, Wildland Crew Boss, Fire Instructor, Swiftwater Helicopter Rescuer, Collapsed Structure Technician, Advanced Rope Rescuer, River Flood Rescuer, Urban Search and Rescue Technician, and Hazardous Materials Technician. He had 17 years of fire fighting experience.

Physical Ability Tests. Applicants must complete the FD's CPAT prior to completing a formal application for hire. Applicants are given a preparation guide for the CPAT in order to train prior to attempting the CPAT. The CPAT is a timed evaluation consisting of the following eight stations: stair climb, hose drag, equipment carry, ladder raise and extension, forcible entry, search, rescue, and ceiling breach and pull. The FD does not have a member physical ability test.

Preplacement Medical Evaluations. The County requires preplacement medical evaluations for all applicants. Components of the medical evaluation include the following:

- Complete medical history
- Physical examination (including vital signs)
- Blood tests: complete blood count, chemistry panel
- Urinalysis
- Urine drug screen
- Spirometry
- Resting EKG
- 12-lead ETT (for abnormal resting EKG or for candidates ≥40 years old)
- Hearing (audiometric) test
- Vision screen

The evaluations are performed in a County contracted clinic under protocols established by the County's Occupational Health Program. Data and findings are sent to the Occupational Health Program for determination of medical clearance for firefighting duties by County employed physicians board certified in occupational medicine.

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Description of the FD (cont.)

Annual Wellness Evaluations. The FD does not require annual medical evaluations for fire fighters. However, the FD and union coordinated an incentive based "Fitness-For-Life" program in which members complete an annual medical evaluation, a physical fitness assessment, and a 12-unit on-line continuing education program. The components of the annual medical evaluation include those of the preplacement medical evaluation with the addition of an annual lipid panel, a chest radiograph every five years, and an annual ETT regardless of age. If the ETT is abnormal, the fire fighter is referred for a CAC scan. If the total CAC score is >100, the fire fighter is referred for a CCTA. If any of the above testing suggests the fire fighter is at risk of sudden loss of consciousness >2% per year, the fire fighter would be placed on restricted duty until more definitive tests or treatments are undertaken. In this case, in both 2011 and 2012, the County contract physician considered the Captain's risk to be less than 2% per year, and the Captain was returned to full duty. The research / academic center cardiologist also recommended the Captain be returned to full duty in 2011 and 2012. The physical fitness assessment, which occurs at the same time as the medical, involves testing of hand, arm, leg, and core strength, flexibility, and aerobic capacity.

Approximately 85-90% of the FD's fire fighters participate in the Fitness-For-Life program each year. To encourage participation and physical fitness, the County offers firefighters a 3% pay bonus for achieving the following benchmarks: 24 push-ups in one minute, either 35 sit-ups in one minute or a 1 minute prone plank, and an age-adjusted VO2 max. For participants in the Captain's age group of 41-50, an aerobic level of 36 ml/kg/min is required. At his last Fitness-For-Life evaluation on February 15, 2012, the Captain qualified for the 3% bonus with 24 push-ups, a 60 second plank, and a VO2 max of 36.1 ml/kg/min.

The medical and physical fitness evaluations are performed by a network of four clinics that contract with the County's Occupational Health Program. A member's primary care physician may conduct the medical evaluation if the evaluation meets the same performance requirements and the results are forwarded to the County's Occupational Health Program for review.

Periodic Fitness-for-Duty Evaluations. The County's Occupational Health Program has established various periodic medical screening programs to comply with various workplace regulations and recommendations. For fire fighters, these include HAZMAT exams for members who are hazardous materials certified, and SCUBA exams for the FD's divers. These examinations must be done at a County contract clinic. In conjunction with the Captain's last "Fitness-For-Life" annual examination on February 15, 2012, he was medically evaluated and cleared for HAZMAT duties. Medical clearance to wear a respirator is completed as part of the preplacement evaluation and not repeated unless a member complains of difficulty using a self-contained breathing apparatus (SCBA).

"For Cause" Fitness-for-Duty Evaluations. The FD may require a member to undergo a fitness-for-duty evaluation conducted by the County's

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Description of the FD (cont.)

Occupational Health Program. These are most commonly ordered when the FD becomes aware that a member has experienced a sudden loss of consciousness (either on or off-duty), or there is impairment observed on-the-job that is consistent with substance abuse. The Captain had no history of being referred for this type of evaluation.

Work Injuries & Illnesses. Members injured on duty are evaluated by an initial treatment facility. When possible, the member provides a job description form to the treating physician. The treating physician submits a return-to-work status report to the FD. The Captain had not experienced any work injuries or illnesses in over three years prior to his death.

Non-Work Injuries & Illnesses. Members who are ill and miss one-or-more shifts must provide a job task form to the treating physician, who provides a medical clearance opinion to the FD. The Captain did not provide the colonoscopy clinic with a job task form, and the clinic did not provide the Captain with return to work clearance, although they do recommend that all patients refrain from working for the rest of the day after the procedure.

Fitness Program. The FD has a mandatory, non-punitive, fitness program. This program allows protected (out of service) time to exercise on equipment available in all fire stations. The Captain exercised daily as part of the fitness program.

Discussion

Atherosclerotic Coronary Heart Disease. In the United States, atherosclerotic CHD is the most common risk factor for cardiac arrest and sudden cardiac death [Meyerburg and Castellanos 2008]. Risk factors for its development include age older than 45, male gender, family history of CHD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [Greenland et al. 2010; AHA 2014]. The Captain had three CHD risk factors (age older than 45, male gender, high blood cholesterol), and was found to have significant CHD on his CCTA in 2011 and his autopsy in 2012.

The most common conditions causing a sudden cardiac death are a heart attack and a primary cardiac arrhythmia. Establishing a recent (acute) heart attack requires any of the following: characteristic EKG changes, elevated cardiac enzymes, or coronary artery thrombus. In this case, an EKG was not performed because the Captain had no heartbeat, cardiac enzymes were not tested, and no coronary artery thrombus was identified at autopsy. Although a heart attack can occur without a coronary thrombus being present [Davies 1992; Farb et al. 1995], NIOSH investigators consider a heart attack less likely due to his lack of angina and results of his most recent ETT.

NIOSH investigators believe a primary cardiac arrhythmia (e.g., ventricular tachycardia/fibrillation) was probably responsible for the Captain's sudden cardiac death. While electrolyte disturbances and/or dehydration from his colonoscopy preparation were possible triggers for the arrhythmia, the Captain's vitreous chemistries strongly suggest these conditions were not present [Madea & Lachenmeier 2005; Collins KA 2013]. Normal hydration was consistent with the following: mod-

Discussion (cont.)

erate physical exertion occurring for 1 to 2 hours, relatively benign environmental conditions (66 degrees Fahrenheit and 29% relative humidity), non-encapsulating clothing, and access to water from canteens.

Finally, we cannot rule out the possibility that the Captain's sudden cardiac death was related to a sedation-related complication during his colonoscopy procedure. However, ventricular arrhythmias associated with colonoscopy sedation are extremely rare, and the reports of these complications occurred during the procedure [George et al. 2010; Miskovitz 2013].

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of sudden cardiac death [Albert et al. 2000]. On-duty cardiac events in fire fighters have been associated with alarm response, fire suppression, and heavy exertion during training (including physical fitness training) [Kales et al. 2003; Kales et al. 2007; NIOSH 2007]. The Captain had climbed a 699-foot, 30-degree sloped hill, which expended about 7 metabolic equivalents (METs), which is considered moderate physical activity [Ainsworth et al. 2011] and represented about 70% of his aerobic capacity (10.3 METS). Given the Captain's underlying CHD, his sudden cardiac death was probably triggered by this moderate physical activity.

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2013a]. This voluntary industry standard provides the components of a preplacement and annual medical evaluation and medical fitness for duty criteria. The Captain had one factor related to medical clearance, coronary artery disease. In 2011, the Captain's CCTA angiogram identified moderate or severe stenotic lesions in 3 coronary vessels. According to NFPA 1582, members with coronary artery disease are at risk for sudden incapacitation and therefore should be precluded from unrestricted fire fighting if any of the following are present:

1) Current angina pectoris even if relieved by medication
2) Persistent significant stenosis in any coronary artery (>70% lumen diameter narrowing) following treatment
3) Lower than normal left ventricular ejection fraction as measured by radionuclide scan, contrast ventriculography, or echocardiography
4) Maximal exercise tolerance of less than 12 METs
5) Exercise-induced ischemia or ventricular arrhythmias observed by radionuclide stress test during an evaluation reaching at least a 12-METs workload
6) History of myocardial infarction, angina, or coronary artery disease with persistence of modifiable risk factor(s) for acute coronary plaque rupture (e.g., tobacco use, hypertension despite treatment or hypercholesterolemia with cholesterol ≥ 180 or low density lipoproteins ≥ 100 despite treatment, or glycosylated hemoglobin > 7 despite exercise and/or weight reduction)

The Captain did not meet criteria #4 or criteria #6 (persistently elevated total cholesterol and LDL cholesterol) [NFPA 2013a].

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Discussion (cont.)

County Occupational Health Program's Fitness-for-Life Program and Risk Assessment. The primary purpose of the Fitness-for-Life program is the promotion of health and physical fitness. A secondary benefit of the program is to ensure medical fitness-for-duty. Current participation in the program is 85-90% per year. To encourage maximum participation in the program and to ensure compliance with fair employment regulations, the County's Occupational Health Program places work restrictions on participants only if their risk of sudden loss of consciousness on-duty is >2% per year. The Occupational Health Program believes that a more aggressive approach to fitness-for-duty would result in a substantial drop in participation rates, thus, counter-productive to the program's primary goal of promoting health and physical fitness.

The County's use of a 2% risk management benchmark derives from the considerations discussed in the background section of the Medical Screening Manual for California Law Enforcement [POST 2010], as well as a recent determination by the U.S. Equal Employment Opportunity Commission (EEOC). The POST Manual recommends the use of a 1% benchmark as an "informal rule-of-thumb" for judging when the risk of sudden loss of consciousness in a setting that could pose a risk of injury to others should be considered excessive [POST 2010]. This benchmark has been adopted by many municipalities in California. However, in 2008, the Federal EEOC issued a Letter of Determination charging the City with violating the Americans with Disabilities Act by disqualifying a police applicant whose risk of an on-duty seizure was estimated to be 1% per year based on the medical literature cited in the POST Manual (Commissioner Griffin vs. City Police Department, June 3, 2008). While the EEOC provided no guidance as how much risk is too high, this action validated a prior decision made by the County to use a more liberal risk management benchmark of 2%, balancing the employment rights of individuals versus the provision of a safe workplace for coworkers and the protection of the public.

To assess the risk of sudden on-duty incapacitation in Fitness-for-Life program participants who have documented coronary disease, the County uses two databases. The first is found in a study of sudden cardiac incapacitation [Bruce and Fisher 1989]. This study considered the Captain to be in the lowest risk group of sudden cardiac incapacitation since he had no history of angina, MI, or sudden cardiac arrest. Despite having risk factors of cholesterol of ≥250, ST depression on ETT, and age 50, his expected risk of sudden cardiac incapacitation was about 0.1% per year.

The second database used by the County is the updated and reanalyzed Framingham Heart Study [D'Agostino et al. 2000]. The D'Agostino et al. formulas calculate risk estimates for sudden death within two years. These two-year risk estimates represent an improvement over the original 10-year Framingham Study estimates by including data from recent follow-up examinations and additional risk factors such as diabetes and baseline CHD. After taking the Captain's baseline coronary insufficiency, age, and poorly controlled cholesterol levels into account, the formula estimates his 2-year risk of sudden cardiac death between 1-2% per year.

The County Occupational Health Program was aware of the NFPA recommendation to restrict

Discussion (cont.)

members, such as the Captain, who have coronary artery disease (on the basis of the CCTA) and hypercholesterolemia. However, the County's extensive use of coronary calcium CT scanning over several years (to evaluate members with ischemic ETT's) had resulted in the identification of dozens of similar members with various degrees of coronary artery disease. Restricting all of these members probably would have greatly decreased program participation and likely embroiled the County in fair employment litigation [Hales 2013].

Finally, as part of the Fit-for-Life program, the County conducts two non-invasive screening tests for CHD: coronary CT scans to generate a CAC score, and the CCTA. Both these tests involve relatively new technologies, and their prognostic value is still being evaluated by ongoing studies. For example, some studies suggest the CAC score improves the prognostic accuracy, resulting in some organizations to recommend their use among asymptomatic patients at intermediate and high risk of cardiac events [Arad et al. 2005; Budoff et al. 2006; Greenland et al. 2010]. Likewise, some studies suggest that CCTA improves the diagnostic accuracy of patients having a major adverse cardiac event (MACE) (e.g., cardiac death, non-fatal myocardial infarction, unstable angina, percutaneous coronary intervention and coronary artery bypass graft) [Cho et al. 2012]. This was particularly true for patients with moderate to severe three vessel disease on CCTA with a MACE above the County's 2% benchmark [Cho el al. 2012]. On the other hand, not all organizations agree of the prognostic ability of the CCTA [Greenland et al. 2010; Mark et al. 2010; Taylor et al. 2010; Hendel et al. 2011].

Recommendations

NIOSH investigators offer the following recommendation, although it unclear if this recommendation would have prevented the Captain's death.

Recommendation #1: Review County policies regarding work restrictions for fire fighters with coronary heart disease identified by various screening tests and risk assessment models/databases.

The Captain was diagnosed with CHD by CCTA suggesting moderate to severe three vessel disease. A relatively recent study suggests these findings increase the risk of a MACE above the County's 2% per year benchmark [Cho et al. 2012]. If the CCTA continues to identify fire fighters with significant CHD, but the results are not used for further evaluation, treatment or work restrictions, the County should revisit whether these screening tests are worth the time and expense.

NIOSH would also like to emphasize the role of the County Occupational Health Program in making return-to-work decisions. As in this case, the consulting cardiologist made a recommendation, but the final decision rested with the County. The occupational medicine physicians staffing the clinics and program are uniquely trained to balance the rights of the employee with the protection of the fire fighter, their crewmembers, and the public.

The following recommendations would not have prevented the Captain's death, but are offered to strengthen the already impressive FD safety and health program.

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Recommendations (cont.)

Recommendation #2: Provide annual medical evaluations to all fire fighters consistent with NFPA 1582 or the IAFF/IAFC Wellness Fitness Initiative.

NIOSH acknowledges the commitment, time, and effort the FD puts into its occupational safety and health program. While the FD provides comprehensive annual evaluations for most fire fighters on special duty assignments (e.g., HazMat) or those participating in the fitness-for-life program, it does not require medical evaluations for all members. This could allow fire fighters with risk factors for CHD, or with CHD, to go undetected. NIOSH investigators recommend the FD explore options to provide mandatory annual medical evaluations to all members. Both NFPA 1582, and the International Association of Fire Fighters (IAFF) / International Association of Fire Chiefs (IAFC) Wellness Fitness Initiative (updated 4th Edition scheduled for release in early 2015) can provide guidance on the components and frequency of these medical evaluations [IAFF/IAFC 2008; NFPA 2014].

Recommendation #3: Perform an annual physical performance (physical ability) evaluation for all members.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the FD develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2013b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters. This could be incorporated into the annual task-level training program.

Recommendation #4: Discontinue exercise treadmill tests on asymptomatic fire fighters at low risk for CHD.

Currently the FD is conducting an ETT on applicants with abnormal resting EKG and on male applicants age 40 and above and female applicants age 50 and above. Members participating in the Fitness-for-Life program are given an annual ETT regardless of the number or severity of their CHD risk factors. While this test has value to ensure the candidate and members have the aerobic capacity needed to complete the essential job tasks of a fire fighter, its use on individuals at low risk for CHD represents an unnecessary medical expense for the FD. The American Heart Association/American College of Cardiology and NFPA 1582 recommend an exercise stress test only for people/FFs at increased risk for CHD defined as one or more coronary artery disease risk factors in male FFs over the age of 45 and female FFs over the age of 55 [Gibbons et al. 2002; NFPA 2013a].

Recommendation #5: Discontinue routine screening chest x-rays for members, unless clinically indicated.

NFPA 1582 recommends an initial baseline chest x-ray and repeat chest x-rays every 5 years or as medically indicated [NFPA 2013a]. Currently, the FD obtains chest x-rays every 5 years for members participating in the "fitness-for-life" program. Routine screening chest x-rays are not recommended by the OSHA hazardous materials (hazardous waste operations and emergency response) standard, unless clinically indicated (e.g., respiratory symptoms) [NIOSH 1985; CFR 2012]. Requiring chest x-rays every 5 years exposes members to unnecessary radiation and is an unnecessary expense for the FD [Tigges et al. 2004].

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Captain Suffers Sudden Cardiac Death During Physical Fitness Training – California

Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Health, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Captain Suffers Sudden Cardiac Death During Physical Fitness Training – California

Appendix A

Timeline of Events

0815 hours: Captain arrives at Fire Camp 14.
0820 hours: The five foremen meet to discuss the day's activities.
0854 hours: Hike begins.
0905 hours: Inmate notices the Captain is breathing hard and sweating.
0909 hours: Captain reaches the top of the ridgeline. The crew begins jogging, while the Captain and the slowest inmate stop to rest for about 4 minutes.
0913 hours: The Captain and the slow inmate jog for 4 minutes.
0917 hours: The Captain and inmate stop to rest.
0919 – 0930 hours: The two walk and rest intermittently.
0936 hours: Both jog to catch up with other crews but slow to a power walk.
0940 hours: The Captain advises the inmate to go ahead of him to finish the walk on time.
0945 hours: The Captain stops sweating and is very flushed. The inmate again offers water but the Captain refuses. The Captain advises the inmate to finish the hike; the inmate walks ahead of the Captain.
0952 hours: The inmate finishes the hike.
1020 hours: All personnel back in camp except the Captain. All search for the Captain in the camp.
1030 hours: A foreman and two inmates form a search team and hike up the hill to search.
1032 hours: The search team splits up to search separate trails.
1055 hours: The foreman locates the Captain along the trail.
1102 hours: Resources are requested to extract the Captain.
1103 hours: Engine 156 (E156), Squad 111 (S111), and Copter 15 are dispatched.
1104 hours: Battalion Chief 6 (BC6) dispatched.
1110 hours: Copter 15 en route.
1111 hours: BC6 on scene.
1121 hours: S111 and E156 on scene.
1122 hours: Copter 15 on scene. Makes an overhead pass and inserts a fire fighter/paramedic with equipment at the scene. Returns to camp to pick up a Captain from E156 and two FF/Ps from S111, and flies them to top of hill.
1132 hours: Advanced life support treatment begins. Medics and crew carry the Captain to Copter 15. Copter 15 en route to hospital.
1157 hours: Copter 15 arrives at hospital.
1220 hours: Captain pronounced dead.

Captain Suffers Sudden Cardiac Death During Physical Fitness Training – California

Appendix B

Autopsy Findings

- Coronary artery atherosclerosis
  - 90% narrowing of the left circumflex coronary artery
  - 80% narrowing of the left anterior descending coronary artery
  - 70% narrowing of the right coronary artery
  - No evidence of a coronary artery thrombus (blood clot)
- Heart size and weight
- Mild bilateral atrial dilatation
- Heart weight of 477 grams (g).
- Heart weights are a function of gender, age, and body weight. The pathologist examining the heart for the coroner's office diagnosed "borderline cardiomegaly" based on the Captain's body weight of 200 pounds. This body weight predicts his heart weight to be 371g with an upper and lower 95% confidence limit of 281g to 489g, respectively [Silver and Silver 2001].
  - NIOSH investigators, however, consider a more accurate body weight to be 220 pounds based on his most recent FD evaluations on 2/14/2012. This body weight predicts a heart weight of 391g with a 95% confidence limit of 296g to 516g [Silver and Silver 2001].
  - Therefore, the Captain's heart weight was within the upper limit of normal.
  - Normal myocardium thickness (left ventricle was 1 centimeter) [Silver and Silver 2001].
  - Microscopic evidence of perivascular fibrosis affecting the left ventricle wall.
- Calcified aortic valve cusp
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative
- No evidence of dehydration based on the presence of clear, yellow urine in the bladder and normal vitreous chemistries [vitreous sodium 136 mmol/L (normal 135-150); potassium 15 mmol/L (normal <15); urea nitrogen 22 mg/dL (normal 8-20); creatinine 0.90 mg/dL (normal 0.6-1.3); chloride 119 mmol/dL (normal 105-135)].

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