



Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation
and Prevention Program

A summary of a NIOSH fire fighter fatality investigation

September, 2010

Lieutenant Suffers Fatal Heart Attack During Training – Ohio

Executive Summary

On March 31, 2010, a 53-year-old male career Lieutenant (LT) reported for duty as the officer on Squad 91. During his shift he participated in the Fire Department's (FD) annual self-contained breathing apparatus (SCBA) endurance evaluation. After completing the first evolution in about 15–20 minutes, the LT complained of shoulder pain and sat down to rest. Shortly thereafter, both on-duty crews were dispatched to separate emergency calls. The LT did not respond with Squad 91, and crew members assumed the LT was either taking a shower or had responded with the other crew. Upon returning to the fire station about 1 hour later, crew members found the LT unresponsive in his bunkroom. Cardiopulmonary resuscitation (CPR) and advanced life support were begun, and the LT was transported to the local hospital's emergency department (ED). Advanced life support continued in the ED for an additional 10 minutes when he was pronounced dead by the ED physician. The autopsy, completed by the County Coroner, listed the cause of death as "acute thrombus of left anterior descending artery" due to "hypertensive atherosclerotic cardiovascular disease." Given the LT's underlying coronary artery disease (CAD), NIOSH investigators concluded that the physical exertion involved in performing the SCBA endurance training triggered his acute heart attack and subsequent cardiac death.

NIOSH investigators offer the following recommendations to address general safety and health issues. It is possible that if some of the recommended programs had been in place, the LT's death may have been prevented.

Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

Provide annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

The following recommendations are made for safety and health reasons and would not have prevented the LT's death.

Provide preplacement medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582.

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

Phase in a comprehensive wellness and fitness program for fire fighters.

Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

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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 1998, Congress appropriated funds to NIOSH to conduct a fire fighter initiative that resulted in the NIOSH “Fire Fighter Fatality Investigation and Prevention Program” which examines line-of-duty-deaths or on duty deaths of fire fighters to assist fire departments, fire fighters, the fire service and others to prevent similar fire fighter deaths in the future. The agency does not enforce compliance with State or Federal occupational safety and health standards and does not determine fault or assign blame. Participation of fire departments and individuals in NIOSH investigations is voluntary. Under its program, NIOSH investigators interview persons with knowledge of the incident who agree to be interviewed and review available records to develop a description of the conditions and circumstances leading to the death(s). Interviewees are not asked to sign sworn statements and interviews are not recorded. The agency’s reports do not name the victim, the fire department or those interviewed. The NIOSH report’s summary of the conditions and circumstances surrounding the fatality is intended to provide context to the agency’s recommendations and is not intended to be definitive for purposes of determining any claim or benefit. For further information, visit the program website at www.cdc.gov/niosh/fire or call toll free 1-800-CDC-INFO (1-800-232-4636).

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Introduction & Methods

On March 31, 2010, a 53-year-old male career LT died shortly after performing an SCBA endurance evaluation. NIOSH was notified of this fatality on April 1, 2010, by the U.S. Fire Administration. NIOSH contacted the affected FD on April 1, 2010, to gather additional information, and on April 26, 2010, to initiate the investigation. On May 3, 2010, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation Team conducted the on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- FD Safety Officer
- Crew members
- LT's family

NIOSH personnel reviewed the following documents:

- FD training records
- FD annual report for 2009
- FD incident report
- Police report
- Witness statements
- FD medical records
- Emergency medical service (ambulance) incident report
- Hospital ED records
- Autopsy report
- Primary care provider medical records

Investigative Results

Incident. On March 31, 2010, the LT arrived for duty at his fire station for his 24-hour shift as the officer assigned to Squad 91. The shift began at 0800 hours, and the LT completed paperwork and other duties while the crew cleaned the station and checked equipment. At 1000 hours, the crew set up the eight-station physical ability course in preparation for the mandatory FD annual SCBA endurance evaluation. Components of the training are listed in Appendix A.

Wearing full bunker gear and SCBA (on air), the crew began the training. Weather conditions at an airport 24 miles away included a temperature of 57 degrees Fahrenheit (°F) and 46% relative humidity [Weather Underground 2010]. After one fire fighter finished the first round and began his 15-minute rest break, the LT began his rotation. The LT's vital signs before the rotation started included a pulse rate of 100 beats per minute, a blood pressure of 122/81 millimeters of mercury (mmHg), and a respiratory rate of 14 breaths per minute. After completing the first round, his low pressure bell activated at 12 minutes, 26 seconds; he had a total operating time of 16 minutes, 15 seconds. At this time, he complained of left shoulder pain, which he attributed to swinging the sledgehammer. The LT decided not to continue the exercise and began his 15-minute rest period. The LT's vital signs after 1 minute of rest included a pulse rate of 130 beats per minute, a blood pressure of 162/94 mmHg, and a respiratory rate of 26 breaths per minute. After a 15-minute rest, his vital signs included a pulse rate of 120 beats per minute, a blood pressure of 122/94 mmHg, and a respiratory rate of 16 breaths per minute.

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Investigative Results (cont.)

At 1224 hours, the FD was dispatched to a medical call. Although the LT was assigned to Squad 91, he did not respond to the call. Some crew members thought the LT was in the shower, while others thought the LT had responded to a second emergency call at 1225 hours (Squad 93).

Additional emergency calls came into the station at 1255 and 1310 hours, keeping the on-duty staff very busy. At approximately 1345 hours, Squad 91 returned to the fire station and realized the LT was missing. They checked the kitchen and the day room, and then found the LT in the officers' dorm room in a kneeling position near his bed (1359 hours).

The LT was unresponsive, not breathing, and without a pulse. His skin was cool to the touch. Resuscitation equipment was retrieved as CPR and advanced life support treatment were begun. A cardiac monitor revealed asystole (no heart beat). The LT was intubated with tube placement verified by the lack of abdominal sounds, but not capnography [AHA 2000]. An intravenous line was placed, and cardiac resuscitation medications were administered. The LT was moved onto a backboard and placed into Rescue 92, which departed the scene at 1421 hours en route to the hospital's ED.

Rescue 92 arrived at the ED (1427 hours), where advanced life support treatment continued. The LT was reintubated as the intubation tube had reportedly become dislodged during transport. External cardiac pacing was attempted without success. The LT's heart rhythm remained in asystole with no cardiac activity. At 1437 hours, the LT was pronounced dead by the attending physician, and resuscitation efforts were discontinued.

Medical Findings. The autopsy, completed by the County Coroner, listed "acute thrombus of left anterior descending artery" as the cause of death due to "hypertensive atherosclerotic cardiovascular disease." Specific findings from the autopsy are listed in Appendix B.

The LT was 75 inches tall and weighed 289 pounds, giving him a body mass index (BMI) of 36.1 kilograms per meters squared. A BMI > 30.0 kilograms per meter squared is considered obese [CDC 2010]. The LT's risk factors for CAD included hypertension (high blood pressure), hypercholesterolemia (high blood cholesterol), and obesity. He had been prescribed an antihypertensive medication since 2003 and complied with taking the medication. An EST was recommended by his primary care physician in 2006. Medical records indicated the test was never performed.

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Description of the Fire Department

At the time of the NIOSH investigation, the FD consisted of one fire station with 28 uniformed personnel (career and part-time) serving 7,100 residents in a geographic area of 9.5 square miles. In 2009, the FD responded to 1,607 calls including 37 fires (12 structure fires, 7 mobile property fires, and 18 other fires), 81 hazardous condition calls, 195 service calls, 132 false alarm calls, 1,060 medical calls, and 102 other calls.

Membership and Training. The FD requires new full-time fire fighter applicants to be 18 years of age (21 years old to drive fire apparatus); have a valid State driver's license; and pass a physical agility test, a written test, a psychological test, an oral interview, a background check, and a State pension fund preplacement medical evaluation prior to being hired. The new hire is on probation for 1 year and must pass a proficiency test after 1 year. Applicants for part-time positions must pass a background check and a State pension fund preplacement medical evaluation (prior to being hired) and a proficiency test (after 6 months). Ohio requires career fire fighters to be trained to the Fire Fighter 2 level. The LT was certified as a Fire Fighter 2, Fire Officer, Driver/Operator, Paramedic, Hazardous Materials Technician, and a Fire Inspector. He had 32 years of fire fighting experience, joining this FD in 1979.

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

- Complete medical history
- Physical examination (including vital signs)
- Complete blood count with lipid panel
- Pulmonary function test
- Resting electrocardiogram (EKG)
- Stress EKG
- Chest x-ray (baseline)

These evaluations are performed by a physician contracted with the City. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for wearing a respirator and fire fighting duties and forwards this decision to the FD. The LT had a preplacement medical evaluation in 1979, but the results were not available to the NIOSH investigator at the time of this report.

Periodic Medical Evaluations. The FD does not require periodic (annual) medical evaluations for members. However, the City grants full-time employees up to 4 hours per year for health risk screening appointments without using their accumulated leave time. An annual SCBA medical clearance is performed by a City-contracted physician. The components of this evaluation include the Occupational Safety and Health Administration respirator medical clearance questionnaire and a pulmonary function test. An annual SCBA facepiece fit test is required by the FD. Members injured on duty must be evaluated by their primary care physician, who makes the final determination regarding return to duty.

Health and Wellness Programs. The FD has a voluntary wellness/fitness program, and exercise equipment is available in the fire station. Fire fighters are given time to exercise but are not taken out of service due to staffing requirements. No annual physical ability test is required.

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Discussion

Atherosclerotic Coronary Artery Disease. In the United States, atherosclerotic CAD 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 CAD, smoking, high blood pressure, high blood cholesterol, obesity/physical inactivity, and diabetes [AHA 2010; NHLBI 2010]. The LT had five CAD risk factors (age over 45, male gender, hypertension, hypercholesterolemia, and obesity) and atherosclerotic CAD on autopsy.

The narrowing of the coronary arteries by atherosclerotic plaques occurs over many years, typically decades [Libby 2008]. However, the growth of these plaques probably occurs in a nonlinear, often abrupt fashion [Shah 1997]. Heart attacks typically occur with the sudden development of complete blockage (occlusion) in one or more coronary arteries that have not developed a collateral blood supply [Fuster et al. 1992]. This sudden blockage is primarily due to blood clots (thromboses) forming on top of atherosclerotic plaques. A blood clot identified at autopsy totally occluded the LT's left anterior descending coronary artery; this finding confirms an acute heart attack. Although the LT did not complain of classic angina chest pain, he did report left shoulder pain. It is unclear if this left shoulder pain represented atypical angina or musculoskeletal pain associated with using the sledgehammer.

Epidemiologic studies have found that heavy physical exertion sometimes immediately precedes and triggers the onset of acute heart attacks and sudden cardiac death [Siscovick et al. 1984; Toffler et al. 1992; Mittleman et al. 1993; Willich et al. 1993; Albert et al. 2000]. Heart attacks 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 LT had performed one round of an SCBA endurance evaluation. This activity expended about 10-12 metabolic equivalents (METs), which is considered moderate - heavy physical activity [AIHA 1971; Gledhill and Jamnik 1992]. Fire fighters expend an average of 12 METs while performing fire fighting duties. Given the LT's underlying CAD, NIOSH investigators concluded that the physical exertion involved in performing the SCBA endurance training triggered his acute heart attack and subsequent death.

Cardiomegaly/Left Ventricular Hypertrophy. On autopsy, the LT was found to have left ventricular hypertrophy (LVH) and an enlarged heart. Both conditions independently increase the risk for sudden cardiac death [Levy et al. 1990]. 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, or chronic cardiac ischemia (reduced blood supply to the heart muscle) [Siegel 1997]. In spite of the LT's treatment, hypertension was most likely responsible for his LVH.

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 2007a]. This voluntary industry standard provides (1) the components of a preplacement and annual medical evaluation and (2) medical fitness for duty criteria.

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Discussion (cont.)

Exercise stress tests screen people at risk for CAD and sudden cardiac death. NFPA 1582 recommends an exercise stress test performed “as clinically indicated by history or symptoms” and refers the reader to Appendix A [NFPA 2007a]. Items in Appendix A are not standard requirements, but are provided for “informational purposes only.” Appendix A recommends using submaximal (85% of predicted heart rate) stress tests as a screening tool to evaluate a fire fighter’s aerobic capacity. Diagnostic stress tests (e.g., maximal or symptom-limiting stress tests) with imaging should be used for fire fighters with the following conditions:

- abnormal screening submaximal tests
- cardiac symptoms
- known coronary artery disease
- two or more risk factors for CAD (in men older than 45 and women older than 55)

Risk factors are defined as hypercholesterolemia (total cholesterol greater than 240 milligrams per deciliter [mg/dL]), hypertension (diastolic blood pressure greater than 90 millimeters of mercury), smoking, diabetes mellitus, or family history of premature CAD (heart attack or sudden cardiac death in a first-degree relative less than 60 years old). This exercise stress test recommendation is similar to that of the American College of Cardiology/American Heart Association (ACC/AHA) and the U.S. Department of Transportation [Gibbons et al. 2002; Blumenthal et al. 2007].

The LT had two of the five risk factors listed above (hypertension and high blood cholesterol) recommended for conducting an exercise stress test. Although the FD did not require an exercise stress test for fire fighters with CAD risk factors, an exercise stress test was recommended by his

primary care physician in 2006. Medical records indicated the test was never performed. If the FD was following NFPA 1582, an exercise stress test would have been performed in 2001 and periodically thereafter. Had it been performed, it could have identified the LT’s underlying CAD. This may have resulted in the LT being referred for further evaluation and treatment, possibly preventing his death.

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Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. It is possible that had some of the recommended programs been in place, the LT's death may have been prevented.

Recommendation #1: Incorporate exercise stress tests following standard medical guidelines into a Fire Department medical evaluation program.

NFPA 1582, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and the ACC/AHA recommend an exercise stress test for male fire fighters older than 45 with two or more CAD risk factors [IAFF, IAFC 2008; Gibbons et al. 2002; NFPA 2007a]. The exercise stress test could be conducted by the fire fighter's personal physician or the FD contract physician. If the fire fighter's personal physician conducts the test, the results must be communicated to the FD physician, who should be responsible for decisions regarding medical clearance for fire fighting duties.

Recommendation #2: Provide annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. These guidelines help to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety

and health of themselves or others. However, the FD is not legally required to follow this standard or this initiative.

Recommendation #3: Ensure that fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Guidance regarding medical evaluations and examinations for structural fire fighters can be found in NFPA 1582 [NFPA 2007a] and in the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF, IAFC 2008]. According to these guidelines, the FD should have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty. The physician should review job descriptions and essential job tasks required for all FD positions and ranks to understand the physiological and psychological demands of fire fighters and the environmental conditions under which they must perform, as well as the personal protective equipment they must wear during various types of emergency operations. This recommendation is made based on review of the FD health and medical programs. The LT's primary care physician had treated the LT for hypertension since 2003 and recommended a stress test in 2006. It is unclear if the LT's physician was aware that his patient was a fire fighter or of NFPA 1582 requirements. Neither of the LT's medical or FD records mentioned medical clearance for duty.

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Recommendations (cont.)

The following recommendations are made for safety and health reasons and would not have prevented the LT's death.

Recommendation #4: Provide preplacement medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582.

Guidance regarding the content of these medical evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. These evaluations are performed to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard or this initiative.

The current preplacement medical evaluation is performed under guidance from the Ohio Police and Fire Pension Fund. This evaluation is not entirely consistent with NFPA 1582. Some missing components include a vision and hearing test, and an added component is the stress test. Neither NFPA 1582 nor the ACC/AHA recommend an exercise stress test in young (< 45 years of age) applicants or in applicants without CAD risk factors. In the opinion of the NIOSH investigators, this represents an unnecessary expense for the FD.

Recommendation #5: Perform an annual physical performance (physical ability) evaluation.

NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, requires the

FD to develop physical performance requirements for candidates and members who engage in emergency operations [NFPA 2007b]. Members who engage in emergency operations must be annually qualified (physical ability test) as meeting these physical performance standards for structural fire fighters [NFPA 2007b].

Recommendation #6: Phase in a comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs to reduce risk factors for cardiovascular disease and improve cardiovascular capacity is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the IAFF/IAFC Fire Service Joint Labor Management Wellness/Fitness Initiative, and in Firefighter Fitness: A Health and Wellness Guide [IAFF, IAFC 2008; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. 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 et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of more than \$1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007]. NIOSH recommends a for-

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Recommendations (cont.)

mal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #7: Use a secondary (technological) test to confirm appropriate placement of the endotracheal tube.

To reduce the risk of improper intubation, the AHA and the International Liaison Committee on Resuscitation published recommendations in the Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [AHA 2000]. These guidelines recommend confirming tube placement by primary and secondary methods. Primary confirmation is the five-point auscultation: left and right anterior chest, left and right midaxillary, and over the stomach. Secondary confirmation requires a technology test, either an end-tidal carbon dioxide detector or an esophageal detector device. In this incident, tube placement was verified by hearing no abdominal sounds; however, secondary confirmation was not performed. In the ED, the endotracheal tube was not in the trachea. It is unclear when the tube had become displaced. It is important to properly secure endotracheal tubes. It is unlikely that this issue contributed to the LT's death because the LT's body was cool to the touch when discovered. We raise this issue only to ensure that future advanced life support resuscitation efforts follow AHA guidelines.

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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).

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Appendix A

SCBA Endurance Training

Each participant will wear full turnout gear and high pressure 4500 psi SCBA (weighing approximately 24 pounds); breathing air from the SCBA until the bottle is empty. Vital signs will be taken for each participant prior to starting, during the 15-minute rest between sessions, and at the end of the training. Readings beyond normal limits (blood pressure in excess of 150/100 millimeters of mercury, pulse rate in excess of 120 beats per minute, and a respiratory rate in excess of 30 breaths per minute) will restrict the participant an additional 15 minutes. Readings beyond normal limits after this 15 minute rest period will require transport to the hospital for further evaluation and treatment.

Station 1 – Ladder Climb – This is the starting point. Each fire fighter shall climb to touch the top rung of the ladder and climb down. No skipped rungs. Proceed to Station 2.

Station 2 – Manual Dexterity – Move balls from the top of cones to the cones on the opposite side. Proceed to Station 3.

Station 3 – Hose Drag – Drag a charged 100' 1¾-inch in diameter hoseline 50' and discharge a stream of water to knock over a target. Proceed to Station 4.

Station 4 – Pike Pole Simulator – Raise the weighted handle 15 times from chest height to extended arm length. Proceed to Station 5.

Station 5 – Hammer Drill – Drive the steel sled to the end of the machine and back using the provided orange composite hammer. Proceed to Station 6.

Station 6 – Fire Fighter Crawl – Crawl through the 50' obstacle. Proceed to Station 7.

Station 7 – Dummy Drag – Lift the rescue dummy (weighing 150 pounds) by the armpits, and drag the dummy a total of 50'. Proceed to Station 8.

Station 8 – Hose Carry – Carry one rolled hose 25'. Pick up another roll of hose and carry it 25' to the starting location.

Proceed to Station 1 and repeat evolutions 1–8 until the participant's SCBA bottle is empty (typically 30–40 minutes).

Lieutenant Suffers Fatal Heart Attack During Training – Ohio

Appendix B

Autopsy Findings

- Atherosclerotic cardiovascular disease
 - Acute thrombus (blood clot) of left anterior descending coronary artery
 - Severe (80%) focal narrowing of the left anterior descending coronary artery
 - Moderate (60%) focal narrowing of the right coronary artery
 - Mild (40%) focal narrowing of the left circumflex artery
 - Microscopic evidence of acute myocardial ischemia
- Hypertensive cardiomyopathy
 - Cardiomegaly (enlarged heart) (heart weighed 570 grams [g]; predicted normal weight is 446 g [between 338 g and 589 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
 - Left ventricular hypertrophy (LVH)
Left ventricular wall thickened (1.5 centimeters [cm])
 - normal by autopsy 0.76–0.88 cm [Colucci and Braunwald 1997]
 - normal by echocardiography 0.6–1.1 cm [Armstrong and Feigenbaum 2001]
 - Microscopic evidence of myocyte hypertrophy, patchy wavy fibers with contraction band myonecrosis, and interstitial fibrosis
- Normal cardiac valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Blood tests for drugs and alcohol were negative

References

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