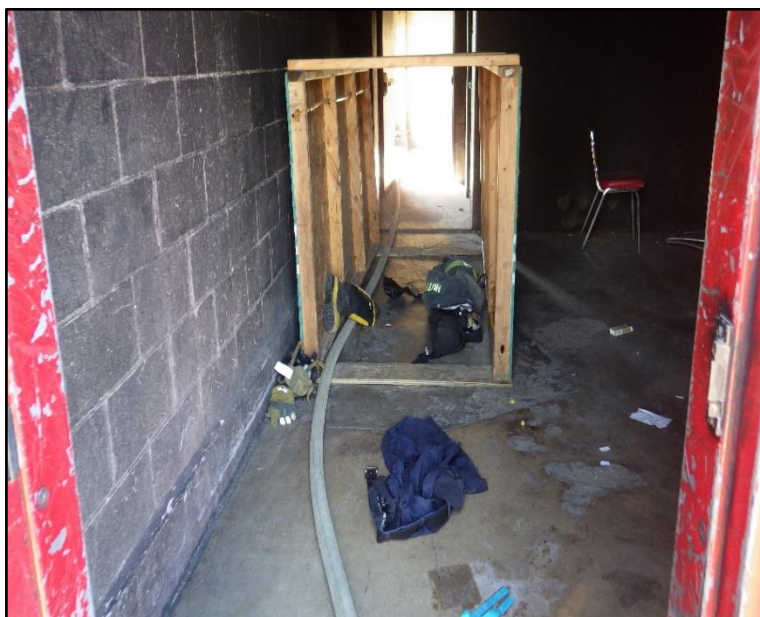




Career Lieutenant Suffers a Sudden Cardiac Event During Fireground Survival Training and Dies 2 days Later-Pennsylvania

Executive Summary

On June 25, 2018, a 62-year-old career Fire Lieutenant (LT) suffered a sudden cardiac event during a training evolution at the fire training center and died 2 days later at the local hospital. The LT was participating in a 3-day International Association of Fire Fighters (IAFF) Fireground Survival Program. He collapsed on the third and final day of training while maneuvering through the entanglement prop of the self-contained-breathing-apparatus (SCBA) maze course. He was wearing full personal protective equipment (PPE) consisting of turnout gear and SCBA. He had exhausted his SCBA's compressed air and was "filter breathing." Filter breathing is a term some firefighters use when they disconnect their mask mounted regulator (MMR) and cover the opening with the lower portion of their PPE hood.



The Lieutenant became unresponsive during the final SCBA entanglement prop on the 3-day survival class and died 2 days later at the hospital.
(Cover Photo Courtesy Fire Department.)

The instructor observing the LT from outside of the entanglement box (see Cover Photo) noted he had stopped moving and was not responding to commands. The instructor opened the entanglement prop and removed the LT to the drill room floor for assessment. The LT was unresponsive, and CPR (cardiopulmonary resuscitation) was begun by fire instructors. On-scene fire department paramedics responded with advanced life support and transported the LT to the local hospital's emergency department. In the emergency department, advance life support measures continued and, although the LT never regained consciousness, his cardiac status improved. He was admitted to the hospital's intensive care unit where subsequent testing revealed anoxic (without oxygen) brain damage. He was removed from life support and pronounced deceased on June 27, 2018. NIOSH investigators concluded that the exertion associated with the training activity triggered a sudden cardiac event in an individual with underlying cardiovascular disease (CVD). The autopsy report listed the cause of death as "hypertensive cardiovascular disease."

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Contributing Factors

- *Undiagnosed hypertensive CVD*
- *Infrequent exercise stress tests (ESTs) for firefighters at risk for CVD*
- *Lack of annual medical clearance for unrestricted firefighting duties which includes training involving heavy physical exertion*
- *Physically strenuous training.*

Key Recommendations

- *Fire departments should provide and require annual medical evaluations for all firefighters*
- *Fire department physicians should ensure symptom-limiting ESTs are provided to firefighters at increased risk of CVD*
- *Fire department physicians should use the information from the annual medical evaluation to make final medical recommendations regarding medical clearance for unrestricted firefighting duties and participation in physically strenuous training exercises*
- *Fire departments should complete annual physical performance evaluations*
- *Fire departments should phase in a mandatory comprehensive wellness-fitness program for all firefighters to reduce CVD risk factors and improve cardiovascular capacity.*

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 firefighter initiative that resulted in the NIOSH Firefighter Fatality Investigation and Prevention Program, which examines line-of-duty deaths or on-duty deaths of firefighters to assist fire departments, firefighters, the fire service, and others to prevent similar firefighter 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

On June 25, 2018, a 62-year-old male LT suffered a sudden cardiac event during fireground survival training and was transported to the hospital where he died two days later. The U.S. Fire Administration notified NIOSH of this fatality on June 28, 2018. In November 2018, a physician and a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Investigation and Prevention Program visited the incident site for an on-site review and investigation.

During the investigation, NIOSH personnel interviewed the following individuals:

- Fire Commissioner
- Deputy Fire Commissioner
- Director, Fire Academy
- Deputy Fire Marshal
- Medical Director for the City
- Mother of the LT.

NIOSH personnel reviewed the following documents:

- Fire department standard operating guidelines
- Emergency medical services (ambulance) report
- Hospital ED records
- Autopsy report
- Fire department medical evaluation records
- Primary care physician records
- Fire department SCBA breathing air test records
- LT's training records
- Witness statements.

Fire Department

The fire department involved in this incident has 63 fire stations. It provides emergency medical and fire suppression services to a population of approximately 1.6 million residents within an area of approximately 141 square miles. For fiscal year 2017, the department had a total of 2,573 budgeted positions, of which 2,447 were uniformed fire and emergency medical services (EMS) providers. In FY18, the positions grew to 2,806 with 2,681 being uniformed. For FY19 that number has further increased to 2,851 positions, with 2,707 uniformed. In FY 2017, the department responded to 314,725 incidents. Of these, 267,266 (85%) were EMS incidents and 47,456 (15%) were fire incidents and 203 non-specific incidents. The department responded to 2,573 working structure fires.

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This fire department has a fire commissioner, who is appointed by the city's mayor; a chief of staff; and deputy commissioners who manage the department. There is also a part-time medical director, a full-time communications director, and four assistant deputy commissioners.

There are four major operating sections: Operations; Logistics; Planning/Risk Reduction; and Finance/Administration. The deputy commissioner for Operations commanded: Fire Suppression, EMS, Special Operations and the Aviation Operations Division. The deputy commissioner for Logistics commanded: Health and Safety, Fire Academy (training), Fire Communications Center, Technical Support Unit (apparatus, equipment, warehouse, water and facilities) and Information Technology. The deputy commissioner for Planning/Risk Reduction commanded: Fire Prevention, Fire Code, EMS Community Risk Reduction, Fire Marshal Units, Performance, Analytics and Management Information Systems. The deputy commissioner for Finance/Administration commanded: Fiscal, Human Resources, Recruitment, Employee Assistance, Employee Relations, and Special Investigations.

At the time of the incident, the city was divided into two divisions. Division 1, which consisted of 5 battalions and 29 fire stations, and Division 2, which had 6 battalions and 34 fire stations. Since this incident, the department has added the following: a platoon-based assistant chief responsible for the entire city; a 3rd division each with their own deputy chief; and two more battalion chiefs, each with their own battalions (the new and existing battalions were re-assigned among the three divisions to limit the number of direct reports to each deputy chief).

The department has 56 engine companies, 27 ladder companies, one heavy rescue company, two squad companies and two fire boats (plus one in reserve). The department operates specialty companies for technical rescue, hazardous materials incidents, and aircraft rescue & firefighting (ARFF). All non-specialized engine companies carry 1,000 feet of 5-inch diameter hose. Two engine companies are designated as squirts, which have 54-foot articulating booms. Two are elevated water towers, which have 50-foot booms. Three engine companies are designated as foam and carry class B foam. Also, Foam Tender 1 operates with Foam 33. Two ladder companies are 85-foot snorkels and have an articulating boom with a platform. Two ladder companies are ladder towers. The remainder of the ladder companies are tractor-drawn aerials.

The staffing on an engine company is an officer and three firefighters. The staffing on a ladder company is an officer and four firefighters. Each squad is staffed with an officer and four firefighters. Rescue-1 is staffed with an officer and five firefighters. Each Division Chief and Battalion Chief is assigned a staff assistant or chief's aide.

The fire department's EMS division consists of 60 medic units, and supervisory staff including EMS field officers. Fifty of the medic units operate on a full-time basis, and ten operate on a part-time basis. The fire department operates an ARFF station at the international airport in the southern part of the city.

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Department members assigned to the operations division work a daily 12/12 shift (0800–2000 and 2000–0800) with four platoons or shifts (on average a 42-hour work week).

Medical and Fitness Requirements for Firefighter Candidates

The fire department requires a pre-placement medical evaluation for all firefighter candidates. Components of the evaluation are as follows:

- Complete medical history
- Height, weight, and vital signs
- Physical examination
- Vision test
- Hearing test
- Blood tests: complete blood count, cholesterol and triglycerides, Sequential Multi-channel Analysis (SMA) 12, cholinesterase level
- Urinalysis
- Urine drug test
- Spirometry
- Resting electrocardiogram (EKG)
- Exercise stress test (EST)
- Chest x-ray.

These evaluations are performed by the city's medical director, who oversees the Medical Evaluation Unit and reports directly to the citywide Office of Human Resources. The city's medical director makes the decision regarding pre-hiring medical clearance for firefighting duties. New hires are required to complete a physical capacity test at the city's fire academy. This is a non-timed performance evaluation of typical firefighting duties. The city's medical director is also responsible for all return-to-duty and promotional medical evaluations ensuring fit for duty status for firefighting duties.

Wellness and Fitness Programs for Members In 2015, municipal administration and the local union negotiated a comprehensive fitness and wellness program for members. A key component of the wellness program included a mandatory biennial medical examination performed by a physician who is board certified in internal medicine, has a background in occupational medicine, is familiar with the requirements of the fire service, and with National Fire Protection Association (NFPA) 1582 and 1583. The required elements of the medical examination are consistent with the above pre-placement medical evaluation with three exceptions: 1) the EST is only for members over the age of 40 years, 2) the chest X-ray is taken every 5 years (or more frequently if indicated), and 3) no urine drug test. In addition to the required elements, there are 5 encouraged, but not required, elements:

- 1) maximal cardiopulmonary test with EKG,
- 2) colonoscopy (baseline and follow-up),

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- 3) annual digital rectal exam,
- 4) for males, examination of the testes and penis,
- 5) for females, vaginal and pelvic exams, pap smears, breast exam, and mammogram.

Oversight for this program is done by a Labor/Management Fitness and Wellness Committee with representatives from the local union, the fire department, labor relations, and the city's risk management division.

The other components of the wellness and fitness program are administered and funded by the local union's health fund with oversight by the Labor/Management Fitness and Wellness Committee. The fitness program uses peer fitness trainers and fitness equipment at fire houses. Participation is voluntary. Members can exercise off duty, or on-duty with time provided by the fire department if it does not interfere with the firefighter's work responsibilities. There is no annual physical ability testing of members.

Training and Experience

The Commonwealth of Pennsylvania does not have prerequisite training or education requirements for an individual to become a firefighter. The department participates with the Pennsylvania State Fire Academy in the Voluntary Participation and Certification Program, which was started in 2003 to provide national certification for department members through the National Board on Fire Service Professional Qualifications and the International Fire Service Accreditation Congress.

To become a member of the fire department, an individual must apply and successfully complete a civil service examination for firefighters. Prospective candidates are selected from the established civil service list by highest test score. The process includes department interviews, a criminal investigation, and a background investigation. If selected for conditional appointment, a candidate must successfully pass a medical examination that complies with NFPA 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments*. Selected candidates are appointed as cadets or recruit firefighters in an extensive 36-week academic, practical, and physical training program at the department's fire academy.

At the fire academy, recruit firefighters are trained in firefighting operations as well as emergency medical services, for which they must obtain state certification as an emergency medical technician. Upon the successful completion of training, recruit firefighters are assigned as probationary firefighters and receive national certification to NFPA 1001, *Standard for Fire Fighter Professional Qualifications*, Fire Fighter I and Fire Fighter II; Hazardous Material Awareness and Hazardous Materials Operations certification; and cadets complete the IAFF Fireground Survival Course and are state-certified as an emergency medical technician (EMT), [NFPA 2013b; NFPA 2015]. A probationary firefighter is assigned to the operations division on either an engine company or a ladder company. As an EMT, firefighters are also assigned as needed to work on basic life support (BLS) and

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advance life support (ALS) medic units. During the probationary period, the probationary firefighter is tested by the fire academy staff at 12 months (written and practical examinations). Recertification for an EMT is every 3 years (24 continuing education hours) and paramedics is every 2 years (36 continuing education hours).

Members assigned to the operations division are required to complete at least 1 hour of training per shift.

Advanced Fireground Survival Course

There are a number of different SCBA training/confidence and/or skills classes being taught around the country with varying levels of difficulty, hazards, challenges, and expected outcomes. The program that the LT was participating in was a formal 3-day fireground survival program developed by the IAFF that combined classroom and practical skills challenges [IAFF 2022].

After a LODD incident in a structural fire in 2014, the NIOSH FFFIPP conducted an investigation and recommended that “Fire department’s should ensure that all fire fighters and officers are trained in Mayday techniques and communications” [NIOSH 2017]. The NIOSH report provided examples of programs designed to teach firefighters some of these techniques (e.g., Mayday techniques and communications). The National Fire Academy classes “Q133-Firefighter Safety, Calling the Mayday” and “H134-Calling the Mayday, Hands-on training” as well as the IAFF Fireground Survival program were identified as resources fire departments could consider. The department selected the IAFF Fireground Survival Training program which was fully implemented in January 2018.

The training program being followed by the department was initially developed by the International Association of Fire Fighters (IAFF), Division of Occupational Health, Safety and Medicine in cooperation with the International Association of Fire Chiefs (IAFC).

Day 1 consisted of program orientation, classroom instruction and SCBA familiarization. The program orientation described size-up, fire behavior (based on National Institute for Standards and Technology (NIST) research, reading smoke, crew integrity (crew continuity), Mayday knowledge and preventing Maydays, SCBA air management, building construction and features, NFPA standards, NIOSH reports and self-survival skills. The program also covered the relationship between cardiovascular fitness, air management and fitness for survival. More SCBA hands-on training followed with emphasis on checking the SCBA and being able to don it in limited or restricted visibility. The students also had to locate a SCBA with a Personal Alert Safety System (PASS) activated and follow a hoseline through a maze set-up.

Day 2 focused on practical skills and built on the skills demonstrated and taught on day 1. This included practical survival skills such as low window hang maneuvers, disentanglement escape using low profile crawling and ladder escape practical skills.

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Day 3 consisted of students using their bail-out gear and performing three jumps from the training trailer. The last portion of day three is a skills practical drill that includes all of the practical evolutions that were taught in the first 2 days as part of a confidence maze.

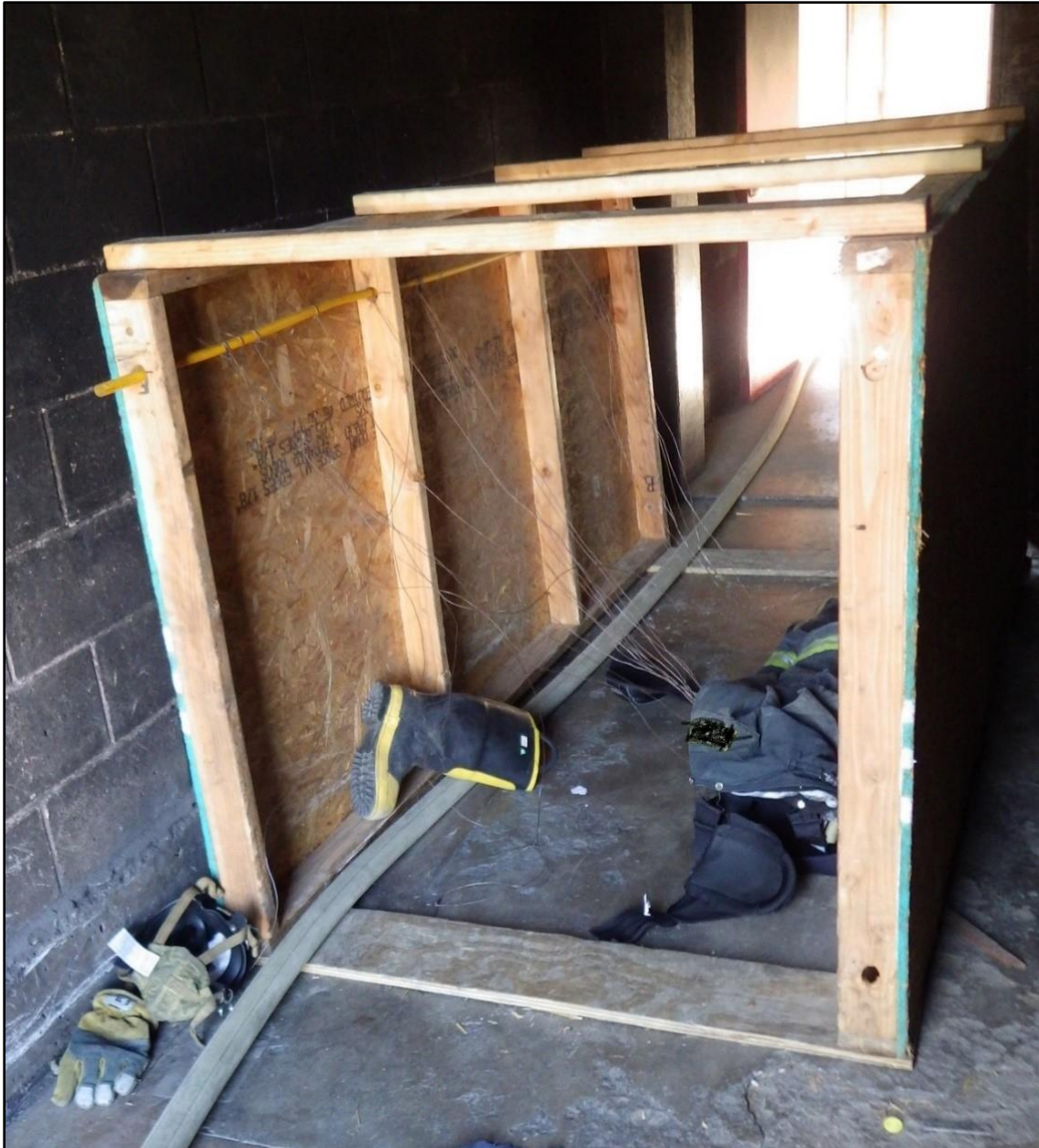
The last training simulation station (prop) in the confidence maze is the disentanglement prop. The disentanglement prop is a box that has a series of wires that simulates wires and entanglement hazards that can happen with a ceiling collapse. The overhead ductwork common in ceilings can entangle firefighters trying to escape. The disentanglement prop simulates this situation (see Photo 1).

As firefighters progress through the prop (with full PPE and SCBA with obscured face pieces), they need to contort their bodies and equipment to get through the hazard. There are wires hanging in the path of travel and the students need to use techniques taught in the class to move, remove, disentangle or get through and exit the box. There are emergency pull handles on the end of the box that will release all of the wires in case of emergency (see Photo 1).

During the practical skills evolutions, the program provided two instructors per skill station with the exception of the ladder escape skill station where there were five instructors. During the SCBA confidence maze course there was one instructor for every student on that skill course and there was an instructor closely monitoring the progress of the victim during his time in the skill course and in the disentanglement prop.

At the time of his medical event, the LT was participating in the day 3 final confidence maze (SCBA disentanglement prop) portion of the advanced fireground survival program (see Cover Photo and Photo 1).

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**Photo 1. Close up photo of the disentanglement prop.
(Photo Courtesy of the Fire Department.)**

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Equipment and Personnel

The minimum staffing in an engine company is an officer and three firefighters. The minimum staffing in a ladder company is an officer and four firefighters. Each squad is staffed with an officer and four firefighters. Rescue 1 is staffed with an officer and five firefighters. Each Division Chief and Battalion Chief are assigned a staff assistant or chief's aide.

All members are assigned portable radios and the radio is electronically linked to the riding position. In the event of an emergency button activation, the fire communications center is able to identify the member by position and relay that information to the incident commander.

At the time of the incident, the department had a Health and Safety Office comprised of the following:

1 Deputy Chief in charge of the Health and Safety Office
1 Captain
4 Lieutenants.

Additionally, the department has four field Deputy Chiefs that serve as operational Incident Safety Officers. They work shifts and respond to "All Hands" notifications or larger fires.

Personal Protective Equipment

The LT was wearing full personal PPE including NFPA compliant coat, bunker pants, helmet, gloves, boots and a 2013 Edition, 5500 psi, 1800-liter, SCBA with an integrated Personal Alert Safety System (PASS). There were no deficiencies found with the victim's PPE or the SCBA's pneumatic or electronic performance. At the training site, breathing air quality certificates were checked for the breathing air source. Breathing air quality was not considered a factor in this incident.

Weather Conditions

At approximately 1454 hours on June 25, 2018, the weather in the immediate area was 81 degrees Fahrenheit and the relative humidity was 34%. The winds were out of the north at 15 mph [Weather Underground 2018].

Investigation

The training that the LT was participating in was part of a 3-day class and focused on fireground survival and respiratory protection training (SCBA training) with both classroom and practical skills learning as described in the Advanced Fireground Survival Course section.

On day three, the LT was in the last prop in the confidence mazed (disentangle prop), accompanied by an instructor. While crawling in the disentanglement prop and attempting to navigate through, the LT became unresponsive. The instructor who was with him noticed a change in the LT's condition and called a code red. (All instructors had radios and the instructor group as well as the safety officer

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monitored the portable radio.) This immediately stopped all training and summoned the additional instructor staff and the EMS unit to his location.

The instructor released the emergency handle (that released the entanglement wires) and removed the LT to the drill room floor for assessment. The LT was unresponsive, and CPR was begun by fire instructors. The on-scene/stand-by fire department paramedics responded with advanced life support and transported the LT to the local hospital's emergency department. In the emergency department, advance life support measures continued and, although the LT never regained consciousness, his cardiac status improved. He was admitted to the hospital's intensive care unit where subsequent testing revealed irreversible brain damage due to lack of oxygen. Brain death examinations/tests (pain response, reflexes, apnea test, and cerebral blood flow) over two days were consistent with clinical brain death. On June 27, 2018, life support measures were withdrawn, and the LT was pronounced deceased at 1453 hours.

The training incident was documented by the department's Fire Marshal's Office (FMO) and investigated by the fire department's Field Incident Safety Office. The departmental investigation noted that all safety protocols and procedures were followed.

Both the department's Fire Marshal's Office and the department's Health and Safety Office as well as the IAFF local assisted NIOSH with this investigation.

Medical Findings

According to the medical records available to NIOSH, the LT's past medical history was notable for high blood pressure (hypertension), high blood lipids (hyperlipidemia), and obesity, all of which put the LT at increased risk for CVD.

Hypertension – The LT was diagnosed with hypertension in 1988 by his primary care provider and treated with diet and exercise. During the years 2006 to 2016, the LT had blood pressure measurements consistent with stage 1 hypertension [Chobanian et al. 2003].

Testing for complications of longstanding hypertension included periodic EKGs, EST, and an echocardiogram. His most recent EKG was conducted in 2016 and was reported to be normal with the exception of a single premature ventricular contraction (PVC). NIOSH reviewed another EKG dated October 6, 2016, performed by a contractor with the fire department's medical evaluation program. This tracing showed no PVCs, but did have a right bundle branch block in the precordial leads. The LT had an EST conducted in 1999 and again in 2010. During his 1999 EST he exercised to 12.9 metabolic equivalents (METs) with no reported ischemic changes or arrhythmias. However, by 2010 he only was able to achieve 10.2 METs before needing to stop the test due to shortness of breath. His tracings showed no ischemic changes, however increasing ventricular ectopy during exercise and multiple PVCs during recovery were noted. Both these findings, ventricular ectopy during exercise and multiple PVCs during recovery, are risk factors for sudden CV events [Frolkis et al. 2003; Jouven et al. 2000]. Although an echocardiogram was performed and reported as normal in 2011, NIOSH investigators

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could not find any further cardiac work-up, work restrictions, or periodic cardiac testing due to these findings.

Hyperlipidemia – The LT’s hyperlipidemia was diagnosed in the 1990s treated by diet and exercise. His most recent results, conducted by the fire department in 2015, showed persistence of his hyperlipidemia, and he was referred to his primary care physician for follow-up [NHLBI 2005].

Obesity – The LT’s had a recorded weight of 243 pounds on 10/6/2016. With a height of 5 feet 4 inches, the LT had a body mass index of 40.4.

Cause of Death

The city’s Office of the Medical Examiner completed an autopsy which listed the cause of death as “Hypertensive Cardiovascular Disease” and “Morbid Obesity” (body mass index of 41.3) as another significant condition. The diagnosis of hypertensive cardiovascular disease was supported by the following findings:

- Cardiomegaly, 580 grams (expected weight = 438 grams)
- Left ventricular hypertrophy, 20/20 millimeters
- Moderate concentric coronary artery vessel wall thickening
- Hypertensive kidneys, on gross examination.

Discussion

Sudden Cardiovascular (CV) Events

Sudden CV events (heart attacks, sudden cardiac death, and strokes) are the leading cause of on-the-job deaths among firefighters, constituting approximately 40%–45% of all duty-related fatalities [Fahy et al. 2020]. Coronary heart disease (CHD) and cardiomyopathies are the most common underlying medical conditions for sudden CV events in the general population and in firefighters [Farioli et al. 2015; Myerburg and Junttila 2012]. Many individuals are unaware of these underlying medical conditions and the sudden CV event is frequently the first sign of their underlying disease [Myerburg and Junttila 2012]. The LT was aware of his hypertension and hyperlipidemia but was unaware of his underlying hypertensive CV disease which includes his moderate CHD.

Single markers or tests are not able to identify people at risk for a sudden CV event. However, the well-established risk factors for CHD can also identify individuals at risk for future sudden CV events. Non-modifiable risk factors include male gender, older age (males >45, females >55), and family history of premature heart disease or sudden cardiac death [AHA 2016]. The LT had two of these risk factors (age and male gender). Modifiable risk factors include hypertension, hyperlipidemia, smoking, diabetes, overweight/obesity, and physical inactivity [AHA 2016]. The LT had three of these risk factors (hypertension, hyperlipidemia, and obesity).

The American Heart Association / American College of Cardiology (AHA/ACC) and the Framingham Heart Study have developed on-line calculators to estimate the risk of future CV events [AHA/ACC

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2020; D’Agostino 2000]. Using the following 12 risk factors (age, gender, race, total cholesterol, LDL cholesterol, HDL cholesterol, use of statins to control cholesterol, systolic blood pressure, blood pressure lowering medication use, diabetes mellitus status, smoking status, and aspirin therapy), the AHA/ACC’s CV risk calculator estimates an individual’s 10-year risk of developing atherosclerotic CVD [AHA/ACC 2020]. Using the LT’s medical information from 2015, he had a 10-year risk of 15.8%. The Framingham Heart Study uses the following 8 risk factors (age, gender, systolic blood pressure, use of antihypertensive medication, current smoking status, fasting total cholesterol, fasting HDL cholesterol, and physician diagnosis of diabetes), to estimate an individual’s 2-year risk of developing a CHD first event [D’Agostino et al. 2000]. Using the LT’s medical information from 2015, his 2-year risk of developing a first CHD event was 2%.

Physical Activity and Sudden Cardiovascular (CV) Events

Strenuous physical activity has been shown to “trigger” heart attacks and sudden death in susceptible individuals (e.g., those with underlying CV disease or CHD) [Thompson et al 2007; Mittleman and Mostofsky 2011]. Since firefighting tasks require heavy physical exertion, this association is also found in firefighters [Hales et al. 2006; Hales 2016; Haller and Smith 2019; Kales et al. 2007; Smith et al. 2016]. The tasks in the fireground survival training are estimated to be approximately 9 METS, which is considered a heavy level of exertion [Ainsworth et al. 2011].

Heat Stress and Heat-Related Illness

The fireground survival training occurred during the summer with a heat index of 80 degrees Fahrenheit. NIOSH investigators were unable to find a patient temperature taken by on-scene first responders, in the ambulance, or in the emergency department, therefore it is unclear if the LT was hyperthermic. It is likely that the heavy physical exertion in turnout gear would have caused some heat stress and which perhaps had some physiologic effects on the cardiovascular system [Wilkinson et al. 2020]. However, given that the training occurred indoors, and the LT reported no symptoms consistent with heat-related illness, NIOSH investigators felt it was unlikely that heat stress/hyperthermia was a significant contributing factor to his sudden cardiac event.

Occupational Medical Standards for Structural Firefighters

To reduce the risk of sudden CV events or other incapacitating conditions among firefighters, NFPA developed 1582, *Standard on Comprehensive Occupational Medical Program for Fire Departments* [NFPA 2013, 2018, 2022]. This voluntary consensus-based standard outlines the specific medical evaluation (physical exam, medical history, ancillary tests) recommended to assess a firefighter’s medical ability to perform their duties safely and effectively. The standard also provides specific medical criteria used to determine fitness-for-duty for certain diseases or conditions. While the 2022 edition of NFPA 1582 is now available, the 2013 edition was in effect at the time of this investigation. The LT had four known health issues addressed in NFPA 1582: hypertension, elevated risk of a sudden CV event, ventricular ectopy (PVCs/non-sustained ventricular tachycardia), and metabolic syndrome.

Hypertension - The 2013 edition of NFPA 1582 recommended referral of firefighters with Stage 1 hypertension (systolic BP 140–159 or diastolic 90–99) to their primary care physician for blood

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pressure control and to “consider” screening for end-organ damage (cardiac findings, nephropathy, retinopathy, etc.). Given the LT’s 30-year history of hypertension, screening for these complications was indicated. While his screening echocardiogram in 2011 was reported as normal, his EST in 2010 was concerning. On the EST in 2010, the LT was unable to achieve the required 12 METs, and his tracing showed ventricular ectopy (non-sustained ventricular tachycardia and numerous PVCs during recovery). According to NFPA 1582, duty restrictions should have been considered despite a normal echocardiogram in 2011, and further cardiac evaluation on a periodic basis should have occurred [NFPA 2013, 2018, 2022]. In addition, the LT’s EKG in 2016 showed a right bundle branch block which, according to NFPA 1582, might compromise the member’s ability to safely perform essential job task(s). Finally, it is unclear if the LT had a dilated eye examination to screen for retinopathy.

Elevated Risk of Sudden CV Events - As mentioned earlier, the LT had a 10-year CV risk of 15.8% and a 2-year risk of developing a first CHD event of 2%. According to NFPA 1582, either one of these findings should have required a symptom-limiting EST to at least 12 METS. If the FF is unable to achieve 12 METS (as the LT could not do in 2010), NFPA 1582 recommends counseling and a prescribed aerobic exercise program to improve fitness [NFPA 2013, 2018, 2022].

Ventricular Arrhythmias and Ectopy – NFPA 1582 states that, “on the basis of increased risk of a sudden cardiac event, ventricular ectopy might compromise a firefighter’s ability to function as an integral member of a team during emergency response” [NFPA 2013, 2018, 2022]. The LT had two types of ventricular ectopy of concern: non-sustained ventricular tachycardia during exercise and PVCs that increased during recovery. NFPA 1582 requires both findings to be followed up with an imaging EST to 12 METS. The LT’s last EST in 2010 did not include an imaging component and the LT did not reach 12 METS.

Metabolic Syndrome - According to the results from the LT’s fire department medical in 2015, he met the criteria for metabolic syndrome (waist circumference > 40 inches, triglycerides > 150 mg/dL, blood pressure > 130/85) [NFPA 2013]. Metabolic syndrome increases the risk for cardiovascular ischemic disease, diabetes, and accelerated hypertension. According to NFPA 1582, members with metabolic syndrome should receive an imaging symptom-limiting EST to 12 METS, be counseled as to lifestyle adjustments, receive an exercise prescription, and be referred to their personal physician for treatment [NFPA 2013]. If the member is unable to achieve an aerobic capacity of 12 METs, the member’s ability to safely perform essential job tasks will be compromised [NFPA 2013].

Contributing Factors

Occupational injuries and fatalities are often the result of one or more contributing factors or key events in a larger sequence of events that ultimately result in the injury or fatality. NIOSH investigators identified the following items as key contributing factors in this incident that ultimately led to the fatality.

- *Undiagnosed hypertensive CVD*
- *Infrequent symptom-limiting exercise stress tests (ESTs) for firefighters at risk for CVD*

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- *Lack of annual medical clearance for unrestricted firefighting duties which includes training involving heavy physical exertion*
- *Physically strenuous training.*

Recommendations

Recommendation #1: Fire departments should provide and require annual medical evaluations to all firefighters.

Discussion: NIOSH applauds the fire department and the local union for implementing a biennial medical examination in 2015. However, NFPA 1582, recommends medical examinations occur on an annual basis [NFPA 2013, 2018, 2022]. Annual medical evaluations help determine a firefighter's medical ability to perform duties without undue risk to the safety and health of self or others. According to the medical records provided to NIOSH, the LT's last fire department medical evaluation was in 2015 with an EKG tracing from 2016.

Recommendation #2: Fire department physicians should ensure symptom-limiting exercise stress tests (ESTs) are provided to firefighters at increased risk of CVD.

Discussion: NFPA 1582 requires all firefighters 40 years and older be assessed for asymptomatic atherosclerotic CVD [NFPA 2013, 2018, 2022]. This assessment includes a 10-year cardiac risk estimate from the American College of Cardiology /American Heart Association, and/or a 2-year cardiac risk estimate from the Framingham Heart Study [AHA/ACC 2018; D'Agostino 2000]. According to NFPA 1582, firefighters with a 10-year risk between 10%–19.9%, or a 2-year risk between 2 to 4% shall be further evaluated with a symptom limiting EST to at least 12 METS with negative tests repeated every 2 to 5 years or when clinically indicated [NFPA 2013, 2018, 2022]. Using the LT's medical information from 2015, he had a 10-year risk of 15.8% and a 2-year risk of 2%. Thus, the LT should have undergone a symptom limiting EST to at least 12 METS and the EST should have been repeated every 2 to 5 years.

It is important to point out that NFPA 1582 and the AHA/ACC, due to validity issues, do not recommend ESTs for young adults (<40 years old) or individuals with low CVD risk. Finally, some fire departments use the EST to assess a firefighter's aerobic capacity rather than as a screening test for CVD. This represents an unnecessary expense for the department because one's aerobic capacity can be easily determined in a non-medical setting (e.g., the Cooper test) [Cooper KH 1968; TREK 2021].

Recommendation #3: Fire departments physicians should use the information from the annual medical evaluation to make final medical recommendations regarding medical clearance for unrestricted firefighting duties and participation in physically strenuous training exercises.

Discussion: In addition to outlining the components of a medical evaluation, NFPA 1582 also provides guidance on when certain medical conditions might require restrictions from full duty [NFPA 2013,

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2018, 2022]. As mentioned in this report’s discussion section, the LT had a number of medical conditions that should have required medical restrictions until further testing was performed or treatment given.

NFPA 1582 defines a fire department physician as “a licensed doctor of medicine or osteopathy who has been designated by the fire department to provide professional expertise in the areas of occupational safety and health as they relate to emergency services.” In this department, the fire department physician was the city medical director in the Medical Evaluation Unit (MEU). Using contractors to conduct medical evaluations, the city medical director reviews not only all the firefighter medical evaluations to make critical medical clearance and return-to-work decisions, but does this for ALL city employees. In addition to these medical clearance responsibilities, the fire department physician is also responsible for 9 other job duties (see section 4.2.1 of the following editions of NFPA 1582) [NFPA 2013, 2018, 2022]. Given the unique job demands of the firefighters, the need to be very familiar with NFPA 1582, and the extensive responsibilities of the fire department physician, the city may want to consider appointing a physician dedicated to the fire department.

Recommendation #4: Fire departments should perform annual physical performance evaluations.

Discussion: NFPA 1500, *Standard on Standard on Fire Department Occupational Safety, Health, and Wellness Program*, states that “members who engage in emergency operations shall be annually qualified as meeting the physical performance requirements established by the fire department” [NFPA 2021]. The standard goes on to state that members not meeting this requirement cannot engage in emergency operations [or training involving heavy physical exertion] and shall be required to enter a physical performance rehabilitation program [NFPA 2021].

The essential job tasks of firefighting require an aerobic capacity of at least 12 METS [Gledhill and Jamnik 1992]. In 2010 the LT was capable of only 10.8 METS and his EST showed had findings suggestive of underlying CVD. At that time, the LT should have been put on restricted duty until further medical testing and evaluations were performed, and he should have entered into aerobic fitness/rehabilitation program [NFPA 2013, 2018, 2022].

Recommendation #5: Fire departments should consider phasing in a mandatory comprehensive wellness-fitness program for all firefighters to reduce CVD risk factors and improve cardiovascular capacity.

Discussion: NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Department Members*, allows firefighters to build and maintain a level of health and fitness which reduce their risk of illness, injury, and premature death [NFPA 2015a]. Fire service health promotion programs have been shown to improve fitness, reduce CHD risk factors, reduce absenteeism, reduce work-related injuries, reduce lost workdays, reduce workers’ compensation claims, reduce medical costs, and have a favorable return on investment with mandatory programs showing the most benefit [Blevins et al.

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2006; Dempsey et al. 2002; Griffin et al. 2016; Kuehl et al. 2013; Poston et al. 2013; Sokolowski et al. 2020].

Currently, the fire department offers a voluntary wellness and fitness program. Again, we applaud the fire department and the local union for their commitment to protecting and maintaining their member's health. However, modifying this program to be a mandatory non-punitive program would benefit all members, particularly members at risk for CVD who choose not to participate. Guidance on comprehensive wellness and fitness programs for firefighters is provided in NFPA 1583 (*Standard on Health-Related Fitness Programs for Fire Department Members*) [NFPA 2015a], the Fire Service Joint Labor Management Wellness/Fitness Initiative [IAFF/IAFC 2018], and the Emergency Services Road Map to Health and Wellness [IAFC 2017].

While not consider contributing factors in this incident, the following recommendations are provided as examples of good safety and health practices for fire departments.

Recommendation #6: Fire Departments and Authorities Having Jurisdiction (AHJs) should ensure training maze props and/or trailers used in advanced SCBA confidence training have adequate safety features such as emergency egress panels, emergency lighting, ventilation and temperature monitoring to measure the ambient temperature inside the maze or prop.

Discussion: Some SCBA maze trailers, buildings or SCBA training props have confined spaces that are used for skills and confidence building of the student, while using full PPE and their SCBA. By design, they may restrict or complicate movement and work area of the student. This is very often combined with restricted vision of the student to simulate a fireground condition that can occur.

These SCBA maze trailers, buildings, and props challenge the firefighters and improve their skills with disentanglement and escaping from a collapse scenario and other challenges firefighters may face while performing their jobs. There is also a key element of skill building by having the firefighter increase their manipulative skills with their particular SCBA and building muscle memory through repetitive skill performance.

Some SCBA maze trailers, buildings or props may be designed and constructed by individual fire departments and may not possess the necessary safety features to provide emergency access for a student in any portion of the maze. Instructors should have complete access to the students in order to remove a student who suffers an emergency medical condition or panics. Although no smoke or IDLH conditions are introduced into these training props, firefighters have experienced serious medical issues while inside the props and had to be extricated before treatment could be rendered (see the additional information section in this report that details a number of NIOSH LODD investigations in SCBA training).

Removing a student or a firefighter who has suffered a debilitating medical condition from inside a severely restricted space is difficult and can be time consuming and labor intensive and may delay

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medical treatment until access can be achieved. Emergency egress panels should be considered as part of the design and construction so instructors and/or medical teams can access, remove and/or treat students. Emergency lighting should also be provided throughout the training maze. In some instances, darkness may be used as the limiting vision factor in place of a blacked out SCBA face piece. In these situations, the instructor should have access to thermal imaging cameras and emergency lighting to monitor and react to any student emergency. Emergency lighting is essential to rapid removal from entanglement hazards and medical evaluation of the student in an emergency.

The students will likely be in full PPE and SCBA and the risk of heat-related illness can be high. Temperature monitoring and ventilation of SCBA training maze trailers, buildings or props is an important safety feature for the students and instructors. A temperature monitoring system should be in place to measure the ambient temperatures and be monitored and kept within the safety guidelines established for the event. Ventilation of the building and/or prop should be considered to control the temperature.

Instructors and safety officers should keep in mind that the students are in full PPE (where the instructors may not be) and the addition of full PPE with SCBA can increase the student's internal temperature and risk of heat-related illness. Periodic wellness/status checks should also be performed on the students. Checkpoints could be SCBA milestone activation, such as End-Of-Service-Time-Indicator (EOSTI), and considerations for stop points when a student isn't clear in their responses during check points, or when they have exhausted all of their air supply.

In this incident, the SCBA training maze (props) were constructed inside of the department's Class A burn building. The props were built to the program guidelines and had all of the appropriate safety releases. The burn building that housed part of the course and props was reported to be designed in the 1970's and constructed in the 1980's. There were no emergency lighting, ventilation nor temperature controls in that building or props. Fire departments should re-evaluate whether routine training should be performed in buildings used for live burns due to potential exposure to lingering carcinogens from combustion by-products.

Additional information on fire service training props can be found in NFPA 1402, Standard on facilities for fire training and associated props [NFPA 2019].

Recommendation #7: As a part of a respiratory protection program, FDs and Authorities Having Jurisdiction (AHJs) should consider which levels of SCBA skills training are essential (awareness level) and which levels are advanced (operations level) and may be optional for members.

Discussion: NFPA 1404 provides guidance on the three levels of respiratory protection. As a part of a fire departments respiratory protection plan, the department should consider minimum levels of respiratory protection for all of its members and also identify advanced levels of SCBA training for specialty companies and other members. SCUBA (Self-Contained Underwater Breathing Apparatus) teams, heavy rescue teams, SCT (structural collapse teams), tunnel rescue teams and others identified

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by the department should have advanced training that is commensurate with their responsibilities and experience. These training disciplines are offered in graduated levels of difficulty and skill levels beginning with awareness as a pre-requisite to operations and then to technician level. The mental and emotional pressure placed on firefighters to complete physically demanding advanced training evolutions (tasks that are beyond essential job task levels as defined by the organization) should be considered, however all of the members should have physical and medical clearance prior to the training.

The pressure to complete physically demanding advanced training evolutions can occur from within the firefighter himself or herself (e.g., “those who may no longer be as physically fit could also feel a similar pressure to push their body beyond its limitations”) or it can come from well-intended members wanting to help the firefighter. The IAFF Fireground Survival training is now offered in awareness and operations levels as well as train the trainer courses. The awareness class is a pre-requisite to the operations level.

If a department or an AHJ decides that advanced (or operations level) survival training involving SCBA maze trailers and confidence building courses are essential respiratory training knowledge, skills, and abilities (KSAs), then the department should have a plan for members who cannot attain the medical clearance for the training. If the respiratory protection program identifies the advanced respiratory training as essential, then they should have a program in place to allow for waivers and/or referrals to a health and wellness program that ensures they are fit for duty and can continue their essential job functions. For advanced respiratory training involving SCBA maze trailers, the FD or AHJ should consider opt-out waivers where a member could remain at a level suitable for all ranks and experience levels (e.g., awareness) similar to high angle, trench and confined space, and hazmat disciplines.

Finally, the fire department and/or AHJ should identify a level of fitness for duty for all firefighters to participate in all levels of respiratory protection training. This involves the commitment to the physical and medical components of NFPA 1500 and NFPA 1582 and 1583.

1. Physical clearance (PAT)
2. Medical clearance (medical evaluation)

NFPA 1500 states firefighters must have an annual Physical Ability Test (PAT). The standard does not identify a specific physical ability test; however, the content should be consistent with the firefighter’s essential job tasks (EJT). Prior to enrollment in a strenuous training program (such as advanced SCBA maze training), the firefighter’s medical clearance must be up to date.

NFPA 1582 requires an annual medical evaluation and like the physical ability test, a list of the firefighter’s essential job functions should be provided by the fire department to the doctor. After the evaluation, the physician makes a recommendation to the fire department about whether the firefighter is medically able to complete those essential job functions without putting the firefighter, their peers,

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or the public at risk. If not, the physician should provide a list of restrictions and the department should determine whether they can accommodate those restrictions (e.g., move to a non-suppression role).

Recommendation #8: Fire departments and training organizations should ensure that established SCBA training protocols are followed for each level of SCBA skills taught, and that students are physically capable and medically cleared to participate.

Discussion: As part of a fire department's Respiratory Protection Program, SCBA training is required and is accomplished through a layered skill level of instruction (NFPA 1404, NFPA 1001). These skill levels range from basic SCBA and introductory level training to advanced level SCBA training.

Accordingly, these levels of SCBA training have significantly different levels of physical and mental capability requirements. NFPA 1404 (NFPA 1404 Standard for Fire Service Respiratory Protection Training 2018, Edition) provides guidance to FDs and AHJ's to address three levels of SCBA instruction. The first level of instruction takes place in a classroom with both didactic and hands-on training. SCBA skills are best learned and then practiced to establish "cockpit time" with that student's particular brand and model SCBA. Repetitive skills training to build muscle memory is a key aspect of all levels of SCBA skills training and there is no substitute for continued hands-on training (NIOSH 2010-13KS, 2014-15TX, 2011-18NC, 2016-07NC). *Note: the term "cockpit time" is a phrase that is used in the military and airline training programs that refer to familiarity and ease of use with that student's particular aircraft and or resource.*

The second level of respiratory protection instruction uses the skills taught in the first level through performance of various emergency response tasks and builds confidence and familiarity with the SCBA and equipment. NFPA 1404 states "This training should take place in a setting that can be safely controlled by the instructor and should be pertinent to the tasks. The use of a training maze is one alternative application for this level of training and builds confidence in the student."

The third level of respiratory protection instruction described in NFPA 1404 describes the advancement to allowing the student to operate using an SCBA under simulated emergency conditions.

These escalating series of respiratory training allow the students to demonstrate their ability to identify, operate and use their SCBA while performing various manipulative skills during emergency scene tasks and helps to build the necessary muscle-memory through repetitive skills necessary to operate an SCBA and react to potential out of air emergencies.

Fire service respiratory training can certainly be a strenuous activity and advanced respiratory training sometimes described as SCBA maze trailer and confidence building KSA's can certainly be classified as strenuous. Fire departments and AHJs who provide this training should ensure that their candidates are physically capable and medically cleared to participate in the training [NFPA 2013, 2015a].

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A number of fire departments across the country have SCBA training props and maze facilities. Physiological strain from exertion or heat stress has been involved in medical LODDs that have occurred in SCBA training and maze trailers. In the section “Additional Information” in this report, we list NIOSH LODD reports that involved SCBA training/maze and/or confidence training. Instructors and safety officers should keep in mind that the students are in full PPE (where the instructors may not be) and the addition of full PPE with SCBA can increase the student’s internal temperature and risk of heat related illness. Periodic wellness/status checks should be performed on the students. These wellness/status checks could be referred to as check points. Check points could be SCBA milestone activation such as EOSTI and considerations for stop points when a student isn’t clear in their responses during check points, or they have exhausted all of their air supply.

Recommendation #9: Fire departments should ensure a comprehensive rehabilitation program and process is in place during training exercises that pose a potential safety and health risk to firefighters.

Discussion: Rehabilitation considerations should be provided during practical training events when the training and safety plan identify a need. NFPA 1500 [NFPA 2022] provides guidance on rehabilitation operations and NFPA 1584, *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercise* provides the components of a comprehensive rehab program [NFPA 2015b, NIOSH 2016].

Rehabilitation efforts should include the following:

1. Medical monitoring
2. Relief from climatic conditions
3. Rest and recovery
4. Rehydration (electrolyte and calorie replacement)
5. Active and/or passive cooling or warming as needed
6. Accountability
7. Release from rehab back to duty status [NFPA 2015b, NIOSH 2016].

Recommendation #10: During advanced SCBA skills and confidence building training programs, students should be cautioned against “filter breathing.”

Discussion: During advanced SCBA skills training class, there may be occasions when (due to the complexity and length of the skills and confidence class) the students run out of SCBA cylinder air in non-IDLH (immediately dangerous to life and health) training scenarios. Some programs instruct students, as a last resort, to disconnect their mask mounted regulator (MMR) and cover the opening with the lower portion of their PPE hood; a maneuver sometimes called “filter breathing.” NIOSH has cautioned against using this method in training and during actual fire suppression for the following reasons.

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First, fire smoke is composed of toxic gases, vapors, and particulates [Fabian et al., 2010]. Like other filter facepiece respirators, using a hood as a filtering material might provide protection against larger particles. However, they will not protect against chemicals, gases, or vapors [NIOSH 2020]. Fire smoke contains dangerous levels of several gases that can cause asphyxiation, for example carbon monoxide and hydrogen cyanide [Fabian et al., 2010]. Teaching students filter breathing during training may increase the risk of filter breathing during an actual fire which puts the firefighter at risk of asphyxiation.

Second, some modern hoods may have vapor and/or moisture barriers to prevent skin burns. Like surgical masks and N-95 respirators, using the hood material as a respiratory filter may increase the amount of carbon dioxide on the inside of the mask or nose cup [Sinkule et al., 2013]. The clinical significance of this amount of carbon dioxide is unclear [Rhee et al., 2021], but theoretically it could increase the firefighters respiratory rate leading to the potential for increased inhalation of carbon dioxide.

Finally, filter breathing has not been shown, or even tested, in laboratory studies to reduce the inhalation of fire smoke particulates. Despite the lack of testing, based on respirator science, it will NOT reduce the inhalation of carbon monoxide gases due to the small molecular size of carbon monoxide relative to the filtering material. During SCBA training, departments should consider a running out of air event, a stopping point of the exercise and not encourage filter breathing in a training exercise.

References

AHA [2016]. [Understand your risks to prevent a heart attack](#). Dallas, TX: American Heart Association. Date accessed, May 17, 2021

AHA/ACC [2020]. [2018 Prevention Guidelines Tool CV Risk Calculator](#). Dallas, TX. American Heart Association/American College of Cardiology. Date accessed, May 17, 2021.

Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR Jr, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS [2011]. [Compendium of physical activities: a second update of codes and MET values](#). Med Sci Sports Exerc 43(8):1575–1581. Date accessed, June 2, 2021.

Blevins JS, Bounds R, Armstrong E, Coast JR [2006]. [Health and fitness programming for fire fighters: does it produce results?](#) Med Sci Sports Exerc 38(Suppl 5):S454. Date accessed, June 3, 2021.

Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL, Jones DW, Materson BJ, Oparil S, Wright JT, Roccella EJ, National High Blood Pressure Education Program Coordinating Committee [2003]. [Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure](#). National Heart, Lung, and Blood Institute; National High Blood Pressure Education Program Coordinating Committee. Seventh report of the Joint National Committee on

Career Lieutenant Suffers a Sudden Cardiac Event During Fireground Survival Training and Dies 2 days Later-Pennsylvania

Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Hypertension 42(6):1206-1252. Date accessed, May 17, 2021.

Cooper KH [1968]. [A means of assessing maximal oxygen uptake](#). JAMA 203:201-204. Date accessed June 3, 2021.

D'Agostino RB, Russell MW, Huse DM, Ellison RC, Silbershatz H, Wilson PW, Hartz SC [2000]. [Primary and subsequent coronary risk appraisal: new results from the Framingham study](#). Am Heart J 139(2):272-281. Date accessed, May 17, 2021.

Dempsey WL, Stevens SR, Snell CR [2002]. [Changes in physical performance and medical measures following a mandatory firefighter wellness program](#). Med Sci Sports Exerc 34(5):S258. Date accessed, June 3, 2021.

Fabian T, Borgerson JL, Kerber SI, Gandhi PD, Baxter CS, Ross CS, Lockey JE, Dalton JM [2010]. [Firefighter exposure to smoke particulates](#). Chicago, IL: Underwriters Laboratory. Date accessed, June 3, 2021.

Fahy RF, Petrillo JT, Molis JL [2020]. [Firefighter Fatalities in the US – 2019](#). Quincy, MA: National Fire Protection Association.

Farioli A, Costas CA, Quarta CC, Kales SN [2015]. [Incidence of sudden cardiac death in a young active population](#). JAHA 4(6):1-4. Date accessed, June 3, 2021.

Frolkis JP, Pothier CE, Blackstone EH, Lauer MS [2003]. [Frequent ventricular ectopy after exercise as a predictor of death](#). NEJM 348:781-790. Date accessed, May 14, 2021.

Gledhill N, Jamnik VK [1992]. [Characterization of the physical demands of firefighting](#). Can J Sport Sci 17(3):207-213. Date accessed, June 2, 2021.

Griffin SC, Regan TL, Harber P, Lutz EA, Hu C, Peate WF, Burgess JL [2016]. [Evaluation of a fitness intervention for new firefighters: Injury reduction and economic benefits](#). Inj Prev 22:181–188. Date accessed, June 2, 2021.

Hales T, Jackson S, Baldwin T [2007]. [Preventing Fire Fighter Fatalities Due to Heart Attacks and Other Sudden Cardiovascular Events](#). Cincinnati, OH. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Publication No. 2007-133. Date accessed, May 19, 2021.

Hales T [2016]. [Why do fireground duties trigger sudden cardiac events in fire fighters?](#) Invited Commentary. Exerc Sport Sci Rev 44(3):89. Date accessed, May 18, 2021.

Career Lieutenant Suffers a Sudden Cardiac Event During Fireground Survival Training and Dies 2 days Later-Pennsylvania

Haller JM, Smith DL [2019]. [Examination of strenuous activity preceding cardiac death during firefighting duties](#). Safety 5(3):50. Date accessed, June 3, 2021.

IAFC [2016]. [A Health Care Provider's Guide to Firefighter Physicals](#). Fairfax, VA: International Association of Fire Chiefs. Date accessed, June 2, 2021.

IAFC [2017]. [Emergency Services Road Map to Health and Wellness](#). Fairfax, VA: International Association of Fire Chiefs. Date accessed, June 2, 2021.

IAFF, IAFC [2018]. [The fire service joint labor management wellness/fitness initiative](#). 4th ed. Washington, DC: International Association of Fire Fighters, International Association of Fire Chiefs. Date accessed, June 2, 2021.

Jouven X, Zureik M, Desnos M, Courbon D, Ducimetière P [2000]. [Long-term outcome in asymptomatic men with exercise-induced premature ventricular depolarizations](#). NEJM 343:826-833. Date accessed, May 14, 2021.

Kales SN, Soteriades ES, Christophi CA, Christiani DC [2007]. [Emergency duties and deaths from heart disease among fire fighters in the United States](#). NEJM 356:1207–1215. Date accessed, May 16, 2021.

Kuehl KS, Elliot DL, Goldberg L, Moe EL, Perrier E, Smith J [2013]. [Economic benefit of the PHLAME wellness programme on firefighter injury](#). Occ Med 63(3):203–209. Date accessed, June 3, 2021.

Mittleman MA, Mostofsky E [2011]. [Physical, psychological and chemical triggers of acute cardiovascular events preventive strategies](#). Circulation 124:346–354. Date accessed, May 17, 2021.

Myerburg RJ, Junttila MJ [2012]. [Sudden cardiac death caused by coronary heart disease](#). Circulation 125(8):1043-1052. Date accessed, May 16, 2021.

NFPA [2013]. NFPA 1582, Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association.

NFPA [2018]. NFPA 1582, Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association.

NFPA [2022]. NFPA 1582, Standard on comprehensive occupational medical program for fire departments. Quincy, MA: National Fire Protection Association.

NFPA [2015a]. NFPA 1583, Standard on health-related fitness programs for fire fighters. Quincy, MA: National Fire Protection Association.

Career Lieutenant Suffers a Sudden Cardiac Event During Fireground Survival Training and Dies 2 days Later-Pennsylvania

NFPA [2015b]. NFPA 1584, Standard on the rehabilitation process for members during emergency operations and training exercises. Quincy, MA: National Fire Protection Association.

NFPA [2013]. NFPA 1981, Standard on open-circuit self-contained breathing apparatus (SCBA) for emergency services. Quincy, MA: National Fire Protection Association.

NFPA [2019]. NFPA 1402, Standard on facilities for fire training and associated props. Quincy, MA: National Fire Protection Association.

NFPA [2021]. NFPA 1500, Standard on fire department occupational safety, health and wellness program. Quincy, MA: National Fire Protection Association.

NHLBI [2005]. [High blood cholesterol: what you need to know](#). Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute. Available online. Date accessed, May 17, 2021.

NIOSH [2016]. [Cadet Dies from Hyperthermia and Exertional Heat Stroke During Indoor SCBA Maze Training—Texas](#). By Baldwin T., Miles S.T., and Tarley J., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2016-05. <https://www.cdc.gov/niosh/fire/pdfs/face201605.pdf>.

NIOSH [2017]. [Career Female Fire Fighter Dies After Becoming Lost and Running Out of Air in a Residential Structure Fire—Pennsylvania](#). By Bowyer, M., Miles, S.T., Moore, P., Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, FACE Report F2014-25 <https://www.cdc.gov/niosh/fire/pdfs/face201425.pdf>.

NIOSH [2020]. [Respirator Fact Sheet. Particulate Respirators](#). Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health.

Poston WS, Haddock CK, Jahnke SA, Jitnarin N, Day RS [2013]. [An examination of the benefits of health promotion programs for the national fire service](#). BMC Public Health 13:805. Date accessed, June 3, 2021.

Rhee MSM, Lindquist CD, Silvestrini MT, Chan AC, Ong JJY, Sharma VK [2021]. [Carbon dioxide increases with face masks but remains below short-term NIOSH limits](#). BMC Infect Dis 21(1):354. Date accessed, May 15, 2021.

Career Lieutenant Suffers a Sudden Cardiac Event During Fireground Survival Training and Dies 2 days Later-Pennsylvania

Sinkule EJ, Powell JB, Goss FL [2013]. [Evaluation of N95 respirator use with a surgical mask cover: effects on breathing resistance and inhaled carbon dioxide](#). Ann Occup Hyg 57:384–398. Date accessed, May 15, 2021.

Smith DL, DeBlois J, Kales SN, Horn G [2016]. [Cardiovascular strain of firefighting and the risk of sudden cardiac events](#). Exercise and Sport Sciences Reviews 44(3):90-97. Date accessed, May 19, 2021.

Sokoloski ML, Rigby BR, Bachik CR, Gordon RA, Rowland IF, Zumbro EL, Duplanty AA [2020]. [Changes in health and physical fitness parameters after six months of group exercise training in firefighters](#). Sports 8(11):143. Date accessed, June 2, 2021.

Thompson PD, Franklin BA, Balady GJ, Blair SN, Corrado D, Estes III NAM, Fulton JE, Gordon NF, Haskell WL, Link MS, Maron BJ, Mittleman MA, Pelliccia A, Wenger NK, Willich SN, Costa F. [2007]. [Exercise and acute cardiovascular events placing the risks into perspective: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity, and Metabolism and the Council on Clinical Cardiology](#). Circulation 115:2358-2368. Date accessed, May 18, 2021.

TREK [2021]. [Aerobic endurance testing](#). Translating Research Evidence and Knowledge. Date accessed, June 3, 2021.

Weather Underground [2018]. Weather history for Philadelphia, June 25, 2018, <https://www.wunderground.com/history/daily/us/pa/philadelphia/KPHL/date/2018-6-25> . Date accessed, May 17, 2021.

Wilkinson AF, Matias AA, Eddy CIK, Soares EM, King JL, Smith DL [2020]. [Physiologic strain of SCBA confidence course training compared to circuit training and live-fire training](#). Appl Ergon 82:102966. Date accessed, June 3, 2021.

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Investigator Information

This incident was jointly investigated by the NIOSH Firefighter Fatality Investigation and Prevention Program, Cardiac and Medical Line of Duty Death Investigations Team in Cincinnati, Ohio, and the Trauma Line of Duty Death Investigation Team in Morgantown, WV.

Stephen T. Miles, Investigator/Safety and Occupational Health Specialist, Dr. Tom Hales, Medical Officer with the Firefighter Fatality Investigation and Prevention Program, Surveillance and Field Investigations Branch, Division of Safety Research, NIOSH located in Morgantown, West Virginia, investigated and co-authored the report, with significant assistance from Dr. Wendi Dick, Medical Officer/Team Lead for the Medical FFFIPP investigations.

Additionally, the NIOSH investigators recognize the collaborative effort and input from the many public safety partners that included the Fire Department's Executive Team, the Health and Safety Division, Fire Training Division, Field Operations and Local 22 of the International Association of Fire Fighters.

Additional Information

A number of fire departments across the country have SCBA training props and maze facilities. Physiological strain from exertion or heat stress has been involved in medical LODDs that have occurred in SCBA training and/or maze trailers or confidence training. Following are NIOSH reports that involved SCBA training/maze and/or confidence training.

- Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Virginia (2008), <https://www.cdc.gov/niosh/fire/pdfs/face200902.pdf>.
- Captain Dies from Hyperthermia and Exertional Heat Stroke While Performing Advanced Survival Training – Texas (2012), <https://www.cdc.gov/niosh/fire/pdfs/face201227.pdf>.
- Cadet Dies from Hypothermia and Exertional Heat Stroke During Indoor SCBA Maze Training - Texas (2018), <https://www.cdc.gov/niosh/fire/pdfs/face201605.pdf>.
- Fire Fighter Trainee Suffers Sudden Cardiac Death During Strenuous Training Drill – Georgia (2008), <https://www.cdc.gov/niosh/fire/pdfs/face200804.pdf>
- Fire Suppression Technician Involved in Maze Training Incident – Texas (1999), <https://www.cdc.gov/niosh/fire/pdfs/face9908.pdf>
- Lieutenant Suffers Sudden Cardiac Death After SCBA Training – Florida (2006), <https://www.cdc.gov/niosh/fire/pdfs/face200602.pdf>
- Fire Fighter Dies During Search and Rescue Training -Ohio, (2000), <https://www.cdc.gov/niosh/fire/pdfs/face200024.pdf>

Career Lieutenant Suffers a Sudden Cardiac Event During Fireground Survival Training and Dies 2 days Later-Pennsylvania

- Lieutenant Suffers a Stroke Following Training and Dies – New York, (2012), <https://www.cdc.gov/niosh/fire/pdfs/face201126.pdf>
- Captain Suffers Cardia Death While Attending Training Drills – New York, (2010), <https://www.cdc.gov/niosh/fire/pdfs/face201022.pdf>
- Probationary Fire Fighter Suffers Sudden Cardiac Death During Maze Drill – Connecticut, (2005), <https://www.cdc.gov/niosh/fire/pdfs/face200438.pdf>
- Fire Fighter Trainee Suffers Sudden Cardiac Death During Maze Training – Arkansas, (2011), <https://www.cdc.gov/niosh/fire/pdfs/face201108.pdf>
- Fire Fighter Suffers Heart Attack During Training and Later Dies – Kansas, (2015), <https://www.cdc.gov/niosh/fire/pdfs/face201502.pdf>
- Senior Captain Suffers Sudden Cardiac Death During Training – Alaska, (2014), <https://www.cdc.gov/niosh/fire/pdfs/face201410.pdf>

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