Cadet Dies from Hyperthermia and Exertional Heat Stroke During Indoor SCBA Maze Training—Texas

Executive Summary

On March 31, 2016, a 32-year-old male career fire fighter cadet (the Cadet) participated in SCBA (self-contained breathing apparatus) maze training inside a "survival house." The training was the final day of a 3-day fireground survival program. He was wearing PPE (personal protective equipment) consisting of full turnout gear with SCBA (on-air). The Cadet was nearing the end of the course when he collapsed. A Mayday was called and the Cadet was removed from the building.

Photo. One of the interior entanglement areas in the survival house. ***(Photo by NIOSH.)***

CPR (cardiopulmonary resuscitation) was begun. Ambulance paramedics who were at the facility for training provided advanced life support (cardiac monitoring, intravenous fluids and medications, and rescue airway). They also initiated active cooling measures because the Cadet's core body temperature was 108.2°F (42.3°C). The Cadet was transported to the hospital's emergency department (ED). Inside the ED, additional cooling measures were taken and advanced life support continued for 57 minutes. Resuscitation efforts were not successful and the Cadet was pronounced dead.

The autopsy report listed "hyperthermia and dehydration" as the cause of death and stated "the exact cause of the hyperthermia is unknown." NIOSH investigators concluded that the physical exertion of the training performed in full PPE/SCBA contributed to the Cadet's hyperthermia and exertional heat stroke.

Key Recommendations

NIOSH offers the following recommendations to help reduce the risk of heat stress-related injuries and fatalities among trainees and fire fighters at this and other fire departments across the country.

- *Ensure that a comprehensive rehabilitation program is in place and operating, which follows recommendations in National Fire Protection Association (NFPA) 1584, Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises.*
- *Strengthen the heat stress program by implementing (or reinforcing) the following recommendations for all training courses:*

Before training:

- *Ensure that trainees are medically cleared by a physician knowledgeable about NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, including the physical demands of fire fighter training and the PPE used.*
- *Educate/re-educate trainees on the importance of reporting off-duty injuries and medical conditions, to include use of medications or dietary supplements.*
- *Have onsite staff (e.g., paramedics) assess trainee risk for heat-related illness prior to strenuous training, to include any training in full turnout gear; consider use of a checklist or other screening tool.*
- *Ensure that trainees (and their instructors) are well-versed on NFPA 1584, to include recognizing early signs and symptoms of possible heat-related illness and understanding potential consequences if not promptly reported and treated.*

During training:

- *Ensure that onsite paramedics regularly monitor trainees for early signs and symptoms of heat-related illness (overall appearance, mental status, vitals, etc.) at a frequency based on training duration, intensity, and other relevant factors.*
- *Ensure that trainees remain well hydrated throughout all phases of physically demanding tasks.*

After training:

- *Ensure that trainees rehydrate during rehab to fully replace fluid losses from sweating. For multi-day exercises, encourage trainees to increase fluid intake during time away from training (off-duty hours, rest days) to reduce the risk of dehydration on subsequent training days [NIOSH 2015].*
- *Solicit input from trainees and instructors about removing barriers (real or perceived) to reporting or seeking medical attention for signs/symptoms of possible heat-related illness.*

The following recommendations would not have prevented the Cadet's death, but NIOSH investigators include them to address general safety and health issues:

- *Ensure that training maze props or trailers used in SCBA confidence training have adequate safety features such as emergency egress panels, emergency lighting, ventilation, and a temperature monitoring system to measure the ambient temperature inside the maze.*
- *In addition to ice water immersion therapy, consider having a second rapid cooling method available that could be accessed quickly during strenuous training.*
- *Provide preplacement and annual medical evaluations for all fire fighters consistent with guidance in NFPA 1582.*
- *Provide fire fighters with medical clearance to wear SCBA as part of the fire department's medical evaluation program.*
- *Perform an annual physical performance evaluation (physical ability test) for fire fighters.*
- *Phase in a mandatory comprehensive fitness and wellness program to benefit all firefighters.*

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Introduction

On March 31, 2016, a 32-year-old male career fire fighter Cadet suffered hyperthermia during training and died. The U.S. Fire Administration notified NIOSH of this fatality on April 1, 2016. NIOSH contacted the affected fire department on April 4, 2016, to gather additional information and initiate the investigation. On April 27, 2016, two safety and occupational health specialists from the NIOSH Fire Fighter Fatality Investigation and Prevention Program and a physical scientist from the NIOSH NPPTL (National Personal Protective Technology Laboratory) visited the incident site for an on-site investigation. The SCBA worn by the Cadet was shipped to the NPPTL for evaluation.

During the investigation, NIOSH personnel interviewed the following people:

- Fire Chief
- Executive Chief of Operations Response Command
- Assistant Chief for Professional Development
- Assistant Chief of Operations
- District Chief for Professional Development
- District Chief of Cadet Training
- Fire Department Liaison Captain
- Arson investigators
- Cadet’s sister
- Cadet’s girlfriend

NIOSH personnel reviewed the following documents:

- Fire department standard operating guidelines
- Fire department annual report for 2015
- Emergency medical services (ambulance) report
- Hospital ED records
- Death certificate
- Autopsy report
- Fire department medical evaluation records
- Primary care physician records
- Fire department SCBA breathing air test records
- Cadet’s training records
- Witness statements

Personal Protective Equipment (PPE)

The Cadet was wearing the full complement of PPE consisting of a station uniform, turnout coat and pants, gloves, boots, hood, helmet, and SCBA with an integrated Personal Alert Safety System (PASS).

The Cadet's SCBA was evaluated in the NIOSH NPPTL and a summary report is enclosed as **Appendix E**. The SCBA was not found to be contributory to the fatality. At the training site, breathing air quality certificates were checked for the breathing air source. Breathing air quality was ruled out as a factor in the Cadet's death.

Weather Conditions

Although this incident occurred inside an air-conditioned fire training center survival house, weather information is provided for context [NOAA 2016]. Weather conditions the morning of the incident included an ambient temperature of 74°F (23.5°C), relative humidity of 93%, heat index of 75°F (24°C), and mostly cloudy skies (0753 hours). Weather conditions at 1200 hours on the two training days before the incident included temperature 76°F (24.4°C), humidity 85%, heat index 77°F (25°C), and mostly cloudy skies on March 31st; and 71°F (21.7°C), humidity 84%, heat index 72°F (22°C), and overcast skies on March 30th.

Structure

SCBA Maze and Prop Building Construction

Note: The following description of the SCBA maze, props, the maze structure, and subsequent building construction information is based on material provided by the fire department and the Texas State Fire Marshal's Office.

The medical incident took place during training in a survival house (see photographs 1–5 and diagrams 1–4 in **Appendix A**). The survival house was a standalone permanent structure (not a maze trailer). It was located on the fire department training site. Live fire is not used in the prop. A smoke generator was used to introduce a realistic atmosphere. The fire department reported that over 7,000 students have gone through the survival house since it was constructed in 2009.

The building housed a training prep room with electronic monitors and seating for students, and a 3,400-square foot SCBA maze course. It had climate control, emergency access, and lighting. The maze was designed to provide students with hands-on-training on how to navigate through entanglement hazards and build confidence in their SCBA and survival skills. The training prop had numerous elevation changes, entanglement challenges, confined areas, and mis-orientation rooms.

Trainees watch an instructional video in the air-conditioned prep room before the evolution begins. Before entering the maze, trainees don the full complement of PPE, including SCBA. They have 30 minutes to complete the course. Students are told to remove their 2nd stage regulator but keep their facepiece on if they run out of air while moving through the course.

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Investigation

For a detailed timeline, see **Appendix B**. On Thursday, March 31, 2016, the final day of a 3-day fireground survival training program, the Cadet arrived at the training facility at 0600 hours. At 0700 hours, the instructional day began. The topic of that day for the 48 trainees was the SCBA maze course located in the survival house. At 0900 hours, the Cadet was in the staging area of the survival house. He was wearing his normal station uniform (t-shirt and pants). He complained to another cadet that he felt hot and he was observed to be sweating. He stood in front of an air conditioner vent to cool off. The thermostat in the area was set to 66°F (19°C).

At 0912 hours, the first cadet entered the SCBA maze course. At 1015 hours, the Cadet was told to get ready to enter the course. He donned his PPE, including SCBA. At 1025 hours, the Cadet entered the course. He was the eighth trainee to enter during this evolution. He was wearing full PPE, including SCBA and facepiece (on-air). The Cadet was instructed to disconnect his mask-mounted regulator from the facepiece if he ran out of air, and continue through the course. He was given instructions to follow the hoseline to the exit. The Cadet acknowledged these instructions.

From 1045 hours to 1100 hours, the Cadet advanced through the course. Several instructors had visual and verbal contact with him. He responded appropriately to questions and moved effectively through the course. At Station 5, the instructor checked each trainee's orientation and fatigue level. If the trainee could not continue, the instructor removed him or her from the course. A total of 3 trainees had already been removed before the Cadet got to Station 5. The instructor questioned the Cadet. He responded appropriately to questions and was still breathing air from his SCBA. There were 4 other trainees were on the course at the same time. Another instructor opened an access door to give instruction to a different trainee. The Cadet saw the open door/light and moved toward it. The instructor told the Cadet to stay on the course and that he was only giving instruction to another trainee. The Cadet responded appropriately and continued on the course. The instructor thought the Cadet had the regulator connected to his facepiece.

From 1107 hours to 1115 hours, an instructor saw the Cadet moving the hoseline and passing by the exit. The instructor reached into the window and pulled the hoseline to show the Cadet that he was on the right path. The instructor heard the Cadet moving and then heard the Cadet stop. A short time later the Cadet's PASS alerted and then went into full alarm. The instructor called out to the Cadet and received no response. The instructor entered the course through the trap door. When the Cadet did not respond, other staff members were alerted that a fire fighter was down and a Mayday was called.

The Cadet was removed from the course and his PPE and SCBA were removed. An instructor noted that the Cadet's SCBA regulator was disconnected from his facepiece. (According to instructors, it was believed that the Cadet had disconnected the regulator after passing Station 6). The Cadet was unresponsive, not breathing, and pulseless. He was hot to the touch. CPR was begun. A medical bag was retrieved and an AED (Automated External Defibrillator) was connected. No shock was advised and CPR continued.

A medic unit at the academy for classroom training responded to the survival building at 1115 hours. Paramedics found the Cadet unresponsive, with CPR in progress. A King Airway® was placed. Tube placement was verified by capnography [AHA 2016]. An IV (intravenous) line was established and cardiac resuscitation medications were administered. An AED was placed, and advised not to shock. Ambulance 52, Engine 61, Squad 46, Paramedic Supervisor 17 (AS017), Paramedic Supervisor 36

(AS036), and PG710 were dispatched to assist.

A cardiac monitor replaced the AED. Asystole was revealed and CPR continued. A second IV line was placed. The Cadet's skin was hot. Cold packs were placed in his groin area to lower his body temperature. PG710, AS017, AS036, and Engine 61 arrived on-scene (1125–1130 hours). Ambulance 52 and Squad 46 were cancelled.

The Cadet's core (rectal) temperature was 107.2°F (41.8°C). After about 20 minutes of CPR, the Cadet was moved for transport to the ED (1136 hours). En route, he was intubated. Tube placement was verified by capnography [Neumar et al. 2010]. His core temperature rose to 108.2°F (42.3°C). Additional attempts to cool the Cadet included cooled saline IV solution, wetting his skin, and fanning. Additional cold packs were placed in his axilla and carotid areas. His heart rhythm remained in asystole during transport. A repeat core temperature read 109°F (42.8°C). The medic unit arrived at the ED at 1151 hours.

Inside the ED, advanced life support continued. Additional cooling with ice packs was performed. Resuscitation efforts continued for 57 minutes but were unsuccessful. An attempt was made to initiate ECMO (extracorporeal membrane oxygenation, a technique that removes blood from the body and returns it after cooling and oxygenation) [Shiraishi and Yokota 2013]; however, this was not successful. The Cadet was pronounced dead at 1248 hours.

Medical Findings

The death certificate and autopsy report listed "hyperthermia and dehydration" as the cause of death. Pertinent autopsy findings are listed in **Appendix F**.

The Cadet's past medical history was noted for the following:

Hyperlipidemia
Diagnosed at his fire department pre-placement physical in September 2015. His screening results included an elevated total cholesterol level of 235 milligrams per deciliter (mg/dL) (desirable < 200), elevated triglycerides (223 mg/dL, normal < 150), slightly elevated LDL "bad" cholesterol (133 mg/dL; desirable < 130), and normal HDL "good" cholesterol (57 mg/dL, desirable > 40) [NHLBI 2005]. He was referred to his primary care physician for follow-up.

Other Medical History
The Cadet sustained a shoulder injury in a minor motor vehicle accident approximately 6 weeks prior to this incident. He saw a private provider and received a prescription NSAID (nonsteroidal anti-inflammatory drug) and an oral corticosteroid. He also took dietary supplements to aid his recovery. About 1 week before the incident, he finished the prescription medications and resumed exercising.

Physical Activity
The Cadet's regular workouts were rigorous and consisted of aerobic and strengthening exercises. Typically, he wore his turnout gear during workouts and got very hot, and would drank large quantities of water before he exercised. The weekend before the incident, the Cadet ran in a 10-kilometer race. Two days before the incident, he trained with other cadets outdoors on exterior maze props. The day before the incident, he participated in a search and rescue drill with 4-person teams and complained to his roommate that he was "really hot" during the drill. That evening, the Cadet completed his exercise routine and told his roommate that he had "nailed" his workout.

Fire Department

At the time of the NIOSH investigation, the fire department consisted of 93 fire stations with 3,789 career uniformed personnel. Its Emergency Response Division operates on a 24/72 work schedule, which equates to a 47.6-hour workweek, including a 24-hour debit day, which is worked approximately once every 36 days.

The fire department serves 2.2 million residents in a geographic area of 656 square miles. It provides aircraft rescue fire fighting for two large commercial airports. It provides automatic aid with one career fire department and one volunteer fire department, which are located in entities within the municipality. The fire department is also part of a regional mutual aid pact that covers transportation emergencies in the greater metropolitan area.

The fire department operates a fire administration office, a fire marshal's office, a fire training academy, an arson division, a logistics center, a fire apparatus maintenance shop, and a fire operations division. The fire Emergency Response Division consists of 93 fire stations, staffing 87 engine companies, 37 ladder or truck companies (including 5 tower ladders), 56 basic life support ambulances with one EMT/B fire fighter and one engineer operator per unit, 34 medic units (advanced life support with two paramedic/fire fighters per unit), 11 squads (non-transport advanced life support units staffed by two paramedics), 3 rescue companies (including one heavy rescue), and 3 shift safety officers. There are 23 districts or battalions in the city. The minimum staffing for each engine company, ladder company, and rescue company is an officer (senior captain or captain), an engineer operator, and two fire fighters. Each district is staffed with a district chief and an incident command technician.

The fire department is rated by the Insurance Services Office as a Class I fire department and is an internationally accredited department through the Commission on Fire Accreditation International. In 2015, the fire department responded to 325,479 incidents (an average of 891 per day): 43,352 fire incidents and 282,127 emergency medical incidents. The average response time for the first unit on scene was less than 6 minutes.

Employment and Training

The fire department requires all applicants to be 18 to 35 years of age, have a valid state driver's license with two or fewer moving violations in the last 36 months, pass a written test, attend applicant orientation, have fingerprints taken, pass a candidate physical ability test (see **Appendix C**), pass a questionnaire/interview, pass a polygraph examination, and pass a background investigation, prior to receiving a conditional job offer. The new member must then pass a preplacement medical evaluation (components described below) and a drug screen.

The fire department requires new "fire fighter/emergency medical technician" applicants to have completed 60 accredited transferable college hours with a grade of "C" or higher or have 2 years of full time (active duty) military service with an honorable discharge. The new member then enters the 9-month fire fighter academy to be trained to the Basic Fire Fighter level and basic emergency medical technician (EMT/B). During the fire fighter academy, the candidate must pass 4 additional physical ability tests (see **Appendix D**). Additional training to the Fire Fighter 1 and 2 level is provided through continuing education and on-the-job training.

The fire department requires new "certified fire fighter/EMT" applicants to have a Texas Commission on Fire Protection Certification – Basic Fire Fighter or higher certification, and complete 15 accredited transferable college hours with a grade of "C" or higher.

The new member then begins a 15-month probation period. The member also enters a 9-month fire fighter academy to be trained to NFPA 1001, *Standard on Fire Fighter Professional Qualifications* standards to include Fire Fighter 1, Fire Fighter II, Hazardous Materials Awareness, and Hazardous Materials Operations [NFPA 2013a]. In addition, the trainee must meet the requirements of National Incident Management System (NIMS) 100 *Introduction to ICS*; NIMS 200 *Basic ICS*; IS 700A *The National Incident Management System, An Introduction*; and IS 800B *The National Response Framework, An Introduction*. In addition to the fire fighter training, the fire fighter trainees receive emergency medical services EMT/B certification, which is a 150-hour curriculum.

After completing the academy, new employees work the following shifts: 24 hours on duty, 24 hours off, 24 hours on duty, 5 days off. Each month, members also work a "debit day" in addition to their regular shift. New members are assigned Phase 1: Two months with an engine company, followed by Phase 2: Two months with a truck company, and then Phase 3: Two months with emergency medical services. Upon completion of probation, the fire fighter trainee becomes a fire fighter.

The fire department requires all Emergency Response Division fire fighters to receive 2 hours of continuing education units training, 1 hour of risk management training, and 24 hours of in-service training per month. The Texas State Fire Commission requires 20 hours of continuing education units per month and the Insurance Services Office requires 8 hours of continuing education units plus eight multi-company drills per month.

The fire department conducts live fire training twice a year at the department's fire academy. The live fire training is compliant with NFPA 1403, *Standard on Live Fire Training* [NFPA 2012a]. Each live fire training evolution uses four engine companies, two ladder companies, one medic unit, and a district chief.

The fire department provides a certification program for all emergency operators, which is a tested position. The fire academy provides the training for the 56-hour certification program, which complies with NFPA 1002, *Standard for Apparatus Driver/Operator Professional Qualifications* [NFPA 2014].

The fire department pays for the state certification process through the Texas State Fire Commission.

The fire department provides an officer development program for members, which is part of the department's career path, plus the opportunity to acquire a college degree. This process uses curriculum from the National Fire Academy; local community colleges, colleges, and universities; and continuing education programs.

The Cadet had completed 5 months of the academy.

Medical Evaluations

Preplacement Medical Evaluations

The fire department requires preplacement medical evaluations for all applicants. Components of this evaluation include the following:

- Complete medical history

- Physical examination (including vital signs)
- Pulmonary function test
- Audiogram
- Vision screen
- Complete blood count with lipid panel
- Urinalysis
- Urine drug screen

The evaluation is performed by a physician contracted with the city. Once this evaluation is complete, the contracted physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the city's personnel director and the fire department.

The Cadet had a preplacement medical evaluation when he joined the fire department in September 2015.

Annual/Promotional Medical Evaluations

Promotional medical evaluations are required by the fire department. Annual medical evaluations are voluntary and are provided at no cost to the fire fighter through the fire department's health insurance plan. The results of these evaluations are not shared with the fire department.

Medical clearance to wear SCBA is not required. Members injured on duty must be evaluated by the worker's compensation physician and the results are provided to city risk management, which makes the final determination regarding return to work.

Wellness/Fitness Programs

Fitness equipment (strength and aerobic) is available in the fire stations. Members are encouraged to exercise 3 hours a week while on-duty. The fire department does not have a comprehensive wellness/fitness program as recommended by the International Association of Fire Fighters/ International Association of Fire Chiefs Wellness Fitness Initiative [IAFF and IAFC 2008].

The Cadet supplemented his academy fitness training by participating in a structured aerobic and strengthening program at a local gym. He was also a fitness trainer.

Discussion

Heat Stress/Strain, Tolerance, Dehydration, Heat Illness, Heat Stroke

Heat stress/strain. Heat stress refers to the overall heat load on a body from all sources–the environment (air temperature, humidity), physical activity (metabolic heat), and protective clothing/PPE [NIOSH 2016]. The body thermoregulates itself by increasing blood flow from the warmer core out to the skin. This helps expel heat to the surrounding environment and facilitates the evaporation of sweat, which is the most effective way for the body to cool itself [Roberts and Wenger 1979]. To support increased skin blood flow, the heart must pump faster and harder (cardiovascular strain). Thermal strain refers to an increase in deep body or core temperature (hyperthermia). If the body lacked the ability to sweat and increase blood flow to the skin, core temperature would rise quickly and reach an unsafe level after about 15 minutes of moderate exercise [Kenney and Johnson 1992].

Heat tolerance. The ability to tolerate heat stress is highly individual. Only about half the variation between people is explained by differences in body size and aerobic fitness [Wyndham 1973]. Heat tolerance can vary day-to-day even in the same person, because of physiologic factors (for example, hydration, nutrition, fatigue, sleep, medications, underlying illness, etc.) [DOD 2003; NIOSH 2016].

Heat acclimatization is the process whereby the body develops improved tolerance to heat-exertion, which requires repeated exposure over the course of days to weeks [DOD 2003; NIOSH 2016]. Once acclimated, work output increases with less physiological strain (lowered heart rate and body temperature), lowering the risk of heat-related illness [DOD 2003; Moseley 1994]. A high level of aerobic fitness provides partial acclimatization, as metabolic heat from exercise confers physiological benefits similar to those from environmental heat [Nunneley and Reardon 2002; Tipton et al. 2008].

Dehydration. The rate of sweating is influenced by environmental heat, physical activity, clothing/PPE, and acclimatization [DOD 2003]. Once acclimated, the sweat rate increases to promote cooling, and fewer electrolytes are lost. Around 1 quart (liter) of sweat is lost during 1 hour of strenuous heat-exertion, which doubles if limited permeability PPE is worn (for example, turnout gear) [DOD 2003; Eglin et al. 2004]. Dehydration worsens hyperthermia and increases the risk of heat-related illness. The reduced blood volume strains the heart, sweat production decreases, core temperature rises, endurance declines, and fatigue occurs earlier [Cheuvront et al. 2010; Sawka et al. 1985].

Proactive replacement of fluid losses is important during exertion-heat stress, as thirst may not arise until more than 2% of body weight is lost [Armstrong and Epstein 1999]. Rehydration is ideally accomplished by drinking small quantities of water at regular, frequent intervals (e.g., every 15–20 minutes) instead of drinking a large volume all at once [McArdle et al. 2010]. This rate of intake also approximates the stomach's emptying rate of about 1.2 quarts per hour [Marzio et al. 1991]. If exertion will be prolonged (e.g., ≥1 to 2 hours) and heavy sweating is likely, electrolyte-carbohydrate sports drinks are recommended to prevent dilutional hyponatremia [Montain and Cheuvront 2008; NFPA 2015a].

Heat-related illness. Although adequate hydration, fitness, and acclimatization protect against heat-related illness, they do not eliminate the risk [ACSM et al. 2007; DOD 2003]. The body's ability to compensate for excess heat can become overwhelmed if evaporative cooling is inhibited by PPE and/or high humidity conditions [DOD 2003].

Exertional heat exhaustion is the most common heat illness among active people. It is characterized by physical exhaustion from excessive cardiovascular strain, where cardiac output cannot meet the demands of skin, muscle, and vital organs such as the heart and brain [Armstrong et al. 1997; DOD 2003]. Other signs/symptoms may include profuse sweating, headache, weakness, light-headedness, tachycardia, etc. Hyperthermia, if present, may be mild to moderate (100.4 to 102.2°F / 38 to 39°C). Some individuals cannot tolerate this level of hyperthermia, while others (such as elite soldiers or athletes) may perform well at even higher temperatures [ACSM et al. 2007; Joy and Goldman 1968]. Once core temperature reaches 102.6°F (39.2°C), the likelihood of heat-exhaustion collapse is around 25%, and as it approaches 104°F (40°C) the majority of people will experience a heat-related illness [NIOSH 2016].

Exertional rhabdomyolysis (rapid breakdown of skeletal muscle) can develop during strenuous exertion as a complication of heat stroke or as a separate injury [DOD 2003; NIOSH 2015]. Classic symptoms include muscle soreness, cramping, and weakness. In some cases, acute renal failure occurs and hospitalization may be necessary to preserve kidney function.

Heat stroke. Heat stroke is a life-threatening emergency of failed thermoregulation with severe hyperthermia (> 104.9°F / 40.5°C) and central nervous system dysfunction, often with loss of consciousness [ACSM et al. 2007]. The brain is particularly sensitive to hyperthermia, but damage can occur to multiple organs [Bouchama et al. 2005; Walter and Carraretto 2016].

Exertional heat stroke typically affects young, active people who are still sweating at the time of collapse [NIOSH 2016]. This differs from nonexertional or "classic" heat stroke which affects the elderly and chronically ill during heat waves, in whom sweating has often ceased. Exertional heat stroke is a particular threat to fire fighters, who perform strenuous duties while wearing gear that traps their body heat [Goforth and Kazman 2015].

Exertional heat stroke can develop even during cool conditions that may be mistakenly considered "safe" [ACSM et al. 2007]. The time to reach severe hyperthermia can be short, ranging from about 30 minutes to several hours [Rav-Acha et al. 2004]. Early signs/symptoms may be subtle or nonspecific, such as headache, nausea, clumsiness, or confusion (for example, failure to follow commands) [DOD 2003; Epstein et al. 1999]. Many exertional heat stroke cases go unrecognized until they collapse.

Mortality rates from studies of soldiers with exertional heat stroke range from about 4% to 22% [Carter et al. 2005; Rav-Acha et al. 2004; Shibolet et al. 1976]. Duration of hyperthermia prior to cooling affects prognosis more than peak core temperature [Shapiro et al. 1973]. Prompt immersion in cold/ice water has been recognized as the most effective method to rapidly lower core temperature and improve outcomes [Casa et al. 2015; Leon and Bouchama 2015; McDermott et al. 2009].

Risk Factors for Heat-Related Illness/Exertional Heat Stroke

A number of predisposing factors for exertional heat illness have been identified (external and internal) [Abriat et al. 2014; Rav-Acha et al. 2004; USAPHC 2016]. These factors are discussed below as they relate to this incident.

<u>External Risk Factors:</u>
Environment. The training took place inside an air-conditioned survival house. Environmental heat was not a factor in this incident.

Repeated strenuous days. The incident occurred on the final day of training which followed 2 consecutive days of other physical activities, consisting of outdoor maze training on day 1 and a search and rescue drill on day 2. The Cadet reported feeling over-heated during search and rescue training, but went on to complete a strenuous workout that night.

The cumulative effect of heat stress is known to increase the risk of exertional heat illness on subsequent days, suggesting that heat stress can have enduring effects [Armstrong et al. 1990; Wallace et al. 2005]. Strenuous activity over multiple consecutive days is likely to have contributed to the heat stress experienced by the Cadet on the day of the incident.

PPE and heavy gear. The Cadet donned full PPE with SCBA 10 minutes before starting the evolution, and collapsed approximately 45 minutes into the course.

Any protective clothing or equipment will compromise heat tolerance by adding weight and altering heat transfer [NIOSH 2016; White and Hodous 1987]. The features of PPE that protect against fire fighting hazards increase the risk of heat-related illness. The insulating layer of the turnout coat traps body heat and the semi-permeable moisture barrier impedes sweat evaporation [Eglin 2007]. SCBA increases the work of breathing [Jones 1991], and the 40–50 pound weight of SCBA/PPE increases the metabolic workload [Haddam VFD 2013]. PPE/SCBA contributed to the Cadet's heat stress.

Exertion. Based on descriptions of the course, estimates from similar activities, and PPE/SCBA considerations, the estimated workload for maze training exceeds 7 METs (metabolic equivalents), which is considered a vigorous level of activity [Ainsworth et al. 2011; NFPA 2015a]. Maze training also had a time limit for successful completion, which would have contributed to its intensity. Prior to the Cadet's collapse, instructors had already removed 3 out of 8 cadets in the evolution due to fatigue or disorientation. The metabolic workload and intensity of maze training contributed to the heat stress/strain experienced by the Cadet.

<u>Internal (Personal) Risk Factors:</u>
The Cadet was young, not overweight, and he had no drug or recent alcohol use. His medical history was not known to include any of the following risk factors: prior heat-related illness, underlying acute illness, chronic disease, or a skin disorder.

Acclimatization. The Cadet had completed 5 months of training at the fire fighter academy, which included physical activity indoors and outdoors. (He was also fit, which partially acclimates the body to heat stress.)

Lack of heat acclimatization was not a factor in this incident.

Fitness. The Cadet exercised regularly to maintain a high level of aerobic fitness and strength.

Poor fitness was not a factor in this incident.

Dehydration. Throughout the 3 days of training, cadets were briefed on preventing dehydration. Access to drinking water was not identified as a problem and the Cadet reportedly drank water during the training. However, approximately 1.5 hours before starting the physical portion of the maze training, the Cadet stood in front of an air conditioner and perspired heavily. The Cadet had reportedly worked out at the gym recently in his turnout gear and had gotten overheated. (Exercising in protective clothing does not improve acclimatization to exercise in the heat, and can in fact worsen dehydration because of increased sweating [Aoyagi et al. 1994; Windle and Davies 1996].)

Laboratory findings at autopsy suggested the Cadet was dehydrated (e.g., mildly elevated concentrations of vitreous sodium and urea nitrogen). Dehydration is likely to have contributed to the Cadet's heat stress.

Sleep loss. Military studies have identified sleep deprivation as a risk for exertional heat stroke [Abriat et al. 2014; NEHC 2007; Rav-Acha et al. 2004]. This may be related to physiological effects such as decreased skin blood flow, reduced sweating, and changes in the secretion of cortisol (a stress hormone) [Abriat et al. 2014; Stephenson et al. 1988]. Studies in athletes have also revealed that risk of heat stroke increases when experiencing multiple simultaneous stressors, such as reduced sleep combined with a sudden increase in physical training and poor nutrition [ACSM et al. 2007].

In this incident, a witness stated that the Cadet did not appear rested when he arrived at the facility at 0600 hours; apart from this, there was no indication that the Cadet was sleep deprived. It is unclear if sleep loss was a contributing factor.

Fatigue. Fatigue increases the risk of exertional heat stroke [ACSM et al. 2007; Armstrong et al. 1990]. Events in the days leading up to the Cadet's collapse suggest he might have been fatigued on the day of the incident. He had completed 2 days of physically demanding fireground training before the incident, as well as a full workout the night before. Autopsy findings suggested dehydration, which can cause fatigue [Cheuvront et al. 2010; DOD 2003].

Although it cannot be known with certainty if the Cadet was experiencing fatigue the day of the incident, events in the preceding days suggest this was likely.

High motivation. Exertional heat stroke has been called the "illness of the over-motivated" and this has been recognized in cases involving soldiers and athletes [Abriat et al. 2014; Cleary 2007; Epstein et al. 1999; Lopez et al. 2011; Rav-Acha et al. 2004]. A strong desire to successfully complete a mission will compel some soldiers to continue pushing themselves despite symptoms of heat illness. Athletes, especially during competition, may ignore early warning signs or symptoms that would normally be protective. In other words, in the setting of heat stress, judgment may be impaired among those who are driven to succeed.

The Cadet's history showed a high degree of personal drive. He served in a reserve component of the U.S. Armed Forces and had a goal to join an elite unit known for intense training and discipline. He was a high school varsity athlete and continued his athletic involvement at the university level. He was self-disciplined to maintain an advanced degree of fitness.

A high level of self-motivation is likely to have played a role in the Cadet attempting to complete the SCBA maze course despite feeling over-heated.

Alcohol and illicit drugs. Recent alcohol intake reduces heat tolerance due to its diuretic effect [Serafin 1996]. Stimulant drugs such as cocaine increase body heat and cause vasoconstriction, which impairs heat elimination [Crandall et al. 2002].

Alcohol and illicit drugs were not factors in this incident.

Medications and supplements. Approximately 1 week prior to the incident, the Cadet finished taking presciption medications. Based on information about drug half-lives, it is likely these medications would have been eliminated from his body by the day of the incident.

The Cadet had been taking an energy supplement containing caffeine, amino acids, vitamins, and other ingredients. He reportedly did not take the supplement the day before or day of the incident. Caffeine is nearly eliminated about 24 hours after being consumed (elimination half-life of approximately 4 to 6 hours) [Benowitz 1990]. Past concerns about caffeine and heat stress have related to its mild diuretic effect and potential for dehydration [Serafin 1996]. Recent reviews have not shown concern for dehydration or heat intolerance with moderate intake (for example, the equivalent of 2 to 4 cups of coffee a day) [Maughan and Griffin 2003; Roti et al. 2006; Zhang et al. 2015]. However, Armstrong et al. [2007] caution that more study is needed on newer low-volume, high-caffeine products that can deliver a large dose in a short period of time. The ingredients in energy supplements apart from caffeine may also be of concern. Following increased reports of adverse events from these supplements, the U.S. Food and Drug Administration issued a warning that energy supplements "are not substitutes for rest or sleep" [FDA 2012]. FDA recommends checking with a physician before starting any dietary supplement, as adverse effects can occur when combined with other supplements or medications [FDA 2016].

The medical examiner's report stated, "The role that these supplements and medications may have played is uncertain."

Summary of Predisposing Factors:
The Cadet was showing signs of feeling over-heated prior to starting training. The reasons for this are not known. Once the evolution began, he was exposed to multiple sources of heat stress--physical exertion, encapsulating turnout gear, SCBA, and the weight of the PPE/SCBA. He had evidence of dehydration, which can worsen heat strain. Heat stress from the days leading up to the incident may have also been a contributing factor.

Recommendations

NIOSH offers the following recommendations to help lower the risk of heat stress-related injuries and fatalities among trainees and fire fighters at this and other fire departments across the country.

***Recommendation #1: Ensure that a comprehensive rehabilitation program is in place and operating, which follows recommendations in NFPA 1584 (*Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises).**

Discussion: Rehabilitation operations should be provided in accordance with fire department standard operating procedures, NFPA 1500 (*Standard on Fire Department Occupational Safety and Health Program)*, and NFPA 1584 [NFPA 2013b, 2015a, 2018b]. Rehabilitation efforts should include the following:

1. Relief from climatic conditions
2. Rest and recovery
3. Active and/or passive cooling or warming as needed for incident type and climate conditions
4. Rehydration (fluid replacement)
5. Calorie and electrolyte replacement as appropriate for longer duration incidents
6. Medical monitoring
7. Member accountability
8. Release [NFPA 2015a].

During this training, cadets were performing strenuous tasks while wearing full turnout gear with SCBA. However, medical monitoring was not performed.

Recommendation #2: Strengthen the heat stress program by implementing/reinforcing the following recommendations for all training courses:

Before training:

- ***Recommendation #2a: Ensure that trainees are medically cleared by a physician knowledgeable about NFPA 1582* (Standard on Comprehensive Occupational Medical**

Program for Fire Departments*), including the physical demands of fire fighter training and the PPE used.*

Discussion: The fire department should ensure that evaluating physicians are familiar with the strenuous tasks and physiological, emotional, and environmental demands of fire fighting and training, the hazards encountered, and the required PPE. Information should also be made available to private physicians who deliver care to off-duty trainees. In addition to NFPA 1582 guidance, a new resource (concise handout) is available to help private providers make informed decisions regarding fire fighter/trainee medical fitness. The *Healthcare Provider's Guide to Firefighter Physicals* addresses routine screening as well as the specific physiological demands and health risks fire fighters and trainees face as "tactical athletes" [IAFC 2016].

- ***Recommendation #2b: Educate/re-educate trainees on the importance of reporting off-duty injuries and medical conditions, to include use of medications or dietary supplements.***

  Discussion: The training facility standard operating guide requires all trainees to "report to their instructor any condition that might impair their ability to participate in scheduled training activities." In addition, "all cadets shall immediately report, or arrange notification for, any injury that occurs on their personal time that is likely to interfere with their training responsibilities" [TDI 2016]. The fire department discourages supplement use and provides each cadet with a two-page document, "The Dangers of Dietary or Performance Enhancing Supplements." Each cadet is required to read and sign the policy.

  Trainees should be educated/reeducated about the importance of disclosing off-duty injuries, illness, treatment, etc. because of potential adverse consequences to their personal safety and that of others. Trainees should be reassured that disclosure will not automatically disqualify them from participation in training.

- ***Recommendation #2c: Have onsite staff (e.g., paramedics) assess trainee risk for heat-related illness prior to strenuous training, to include any training in full turnout gear; consider use of a checklist or other screening tool.***

  Discussion: A systematic pre-participation assessment can assist onsite staff to better assess each trainee's suitability for training and identify any recent issues (illness, injury, medications, sleep deprivation, etc.) or ongoing factors (obesity, chronic disease, a tendency to be stoic, etc.) that may require closer monitoring and further evaluation.

  Screening strategies from other groups may be helpful to develop a checklist or other screening tool specific to fire fighter trainees. For example, the U.S. Army created a "Risk Assessment Worksheet" to assess soldiers prior to missions or tasks that would require physical exertion in hot conditions [TRADOC 2016]. The assessment takes into account risk considerations such as projected workload, the workload on the previous 2 days, the number of days acclimated to the heat, hours slept during the past 24 hours, etc. For athletes wanting to play competitive sports, an expert panel developed a "Heat-Illness Screening Instrument" for athletic trainers to use when conducting pre-participation sports physicals. The instrument includes a brief questionnaire, several baseline measures (BMI, urine specific gravity), and a scoring system to estimate each athlete's level of risk [Eberman and Cleary 2011].

- ***Recommendation #2d: Ensure that trainees (and their instructors) are well-versed on NFPA 1584, to include recognizing early signs and symptoms of possible heat-related illness and understanding potential consequences if not promptly reported and treated.***

  Discussion: It is important for trainees and instructors to be vigilant for early signs and symptoms of excessive heat strain or heat-related illness, which may be subtle to detect and may be overlooked or ignored by trainees who are highly motivated to perform well. Trainees should be encouraged to promptly report issues for their own safety and that of others, and should be reassured that doing so will not automatically disqualify them from participation in training.

During training:

- ***Recommendation #2e: Ensure that onsite paramedics regularly monitor trainees for early signs and symptoms of heat-related illness (overall appearance, mental status, vitals, etc.) at a frequency based on training duration, intensity, and other relevant factors.***

  Discussion: The fire department standard operating guide 6.2G states, "Training instructors shall be responsible for continuous monitoring of all participating personnel for signs and symptoms of heat and cold stress." Emergency medical equipment (basic life support and an AED) were readily available and used. The instructors closely watched the cadets during each evolution but did not take vital signs or screen for signs/symptoms.

  Prior to each evolution that is physically demanding or conducted in full turnout gear, each trainee should be formally assessed to determine his or her suitability to continue training, as an enhanced margin of safety. Obtaining vital signs before training can be useful as part of the initial screening, as well as providing a set of baseline values to compare against subsequent assessments.

- ***Recommendation #2f: Ensure that trainees remain well hydrated throughout all phases of physically demanding tasks.***

  Discussion: Specific recommendations on fluid intake to prevent dehydration during physical exertion are outlined in the NFPA and NIOSH documents below.

  - *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises*, NFPA 1584 [NFPA 2015a].
  - *Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments*, NIOSH Publication No. 2016-106 [NIOSH 2016].
  - *Evaluation of Heat Stress, Heat Strain, and Rhabdomyolysis During Structural Fire Fighter Training*, NIOSH Health Hazard Evaluation Report 2012-0039-3242 [NIOSH 2015].

After training:

- ***Recommendation #2g: Ensure that trainees rehydrate during rehab to fully replace their fluid losses from sweating; for multi-day exercises, encourage trainees to increase fluid intake during time away from training to reduce the risk of dehydration on subsequent training days [NIOSH 2015].***

Discussion: Fluid losses can accumulate throughout the course of training that takes place over consecutive days, in addition to fluid losses that occur during off-duty activities. Encourage trainees to increase their intake of fluids during time away from training (off-duty hours, rest days) while avoiding drinks containing high amounts of caffeine or sugar, and alcohol [NIOSH 2015].

- ***Recommendation #2h: Solicit input from trainees and instructors about removing barriers (real or perceived) to reporting or seeking medical attention for signs/symptoms of possible heat-related illness.***

  Discussion: Some of the best "eyes and ears" for the baseline functioning, health status, and well-being of trainees may be those who know them best, e.g., fellow trainees. However, trainees may be reluctant to report issues about themselves or fellow trainees out of concern for the potential impact this could have on training progression. Gaining awareness of any reluctance to report health or safety concerns is an initial step in understanding the barriers so that they can be minimized or removed.

Recommendation #3: Ensure that training maze props or trailers used in SCBA confidence training have adequate safety features such as emergency egress panels, emergency lighting, ventilation, and a temperature monitoring system to measure the ambient temperature inside the maze.

Discussion: Some training props (such as an SCBA training maze) contain confined space areas for skill building of fire fighters by restricting the maneuvering/working area of the fire fighter. Combined with reduced visibility and other conditions designed to simulate fireground conditions, these props challenge the fire fighters and improve their skills and confidence in using SCBA. Many of these training mazes are designed and constructed by fire departments and may not possess all of the necessary safety features to respond to medical emergencies of users. Although no fire or smoke conditions are introduced into these training maze props, fire fighters have experienced serious medical conditions while inside the props and have had to be extricated before treatment could be rendered. Extricating a fire fighter who has suffered a debilitating medical condition inside a severely restricted space is difficult and can be time consuming and labor intensive. Emergency egress panels that would allow for easy removal of fire fighters experiencing a medical event should be located inside the confined space areas. Emergency lighting should be provided for users and rescuers. The fire fighters often have PPE, SCBA, and other equipment that may have to be disentangled in order to remove them, and emergency lighting will aid in the extrication and removal. Many training mazes are outdoor semi-permanent trailer designs that are exposed to temperature extremes. A temperature monitoring system inside the training maze would allow the instructors to monitor temperature extremes and adjust the training accordingly. Ventilation of training mazes should be used to control the temperatures. Additional information concerning training props can be found in NFPA 1402, *Guide to Building Fire Service Training Centers* [NFPA 2012b].

In this incident, the SCBA survival house prop was well designed with air conditioning and lighting throughout. It contained a preparation room (staging area with chairs for students) and was well staffed with adequate instructors throughout the survival house. Once the students entered the course, instructors could monitor them throughout the prop. Trap doors were located throughout the maze that the instructors could use to access students throughout the prop. However, there was no emergency lighting. Emergency lighting is important in the event of an emergency on the survival course. Other students and instructors can immediately take actions in the event an emergency activation of lighting is switched on and audible instructions given.

The Cadet experienced a medical condition inside the training maze and had to be removed before medical assistance could be provided. When he experienced the medical condition, he was in a portion of the training maze that was immediately accessible to the instructors through trap doors and he was removed and treated.

The following recommendations would not have prevented the Cadet's death, but NIOSH investigators include them to address general safety and health issues.

Recommendation #4: In addition to ice water immersion therapy, consider having a second rapid cooling method available that could be accessed quickly during strenuous training.

Discussion: The Cadet presented in acute circulatory failure, which may be attributable to myocardial damage from profound hyperthermia and has poorer prognosis [Drezner et al. 2007; Zahger et al. 1989]. Ice water immersion therapy, AED, and paramedics were available on-scene. Since the Cadet was in cardiac arrest, resuscitation and transport to the ED were a priority. Although emergency medical services and ED personnel applied cold packs and administered cooled IV fluids, these methods are not very effective to rapidly lower core temperature [ACSM et al. 2007; Binkley et al. 2002]. Immersion in ice water, however, may not be feasible when resuscitation or other lifesaving interventions are required at the same time. Alternative cooling methods have been recommended by others. For example, when heat stroke victims must be positioned on a backboard or stretcher for delivery of CPR or other lifesaving interventions, the U.S. military recommends placing iced sheets over the body coupled with fanning [DOD 2003; TRADOC 2016]. For similar situations, a multi-disciplinary athletic task force recommends applying ice water towels to the head, trunk, and extremities combined with application of ice packs to the neck, axillae, and groin [Drezner et al. 2007].

For an extra margin of safety during arduous training, it is recommended that an additional rapid cooling method be available, so that life support and cooling measures can be administered at the same time.

Recommendation #5: Provide preplacement and annual medical evaluations for all trainees/fire fighters consistent with guidance in NFPA 1582.

Discussion: Preplacement and annual evaluations are performed to determine a fire fighter's or trainee's medical ability to perform duties without presenting a significant risk to the safety and health of himself/herself or others. Medical evaluations should be consistent with NFPA 1582 recommendations [NFPA 2013c, 2018a]. Guidance is also available in *The Healthcare Provider's Guide to Firefighter Physicals*, which assists private physicians to provide annual occupational exams for fire fighters [IAFC 2016].

At the time of the site visit, annual medical evaluations for fire fighters were voluntary and were provided through the department's health insurance plan. The fire department's preplacement exam did not include a chest x-ray or resting 12-lead electrocardiogram (EKG), which NFPA 1582 recommends for trainees (Annex A.6.1.2) [NFPA 2018a].

Recommendation #6: Provide fire fighters with medical clearance to wear SCBA as part of the fire department's medical evaluation program.

Discussion: The Occupational Safety and Health Administration (OSHA) respiratory protection standard requires that private industry employers provide medical evaluations and clearance for workers who use respirators to make sure they are medically fit to tolerate the additional physical and mental stress [29 CFR 1910.134; OSHA 2012]. This requirement extends to public workers in states that operate their own OSHA-approved occupational safety and health plans [OSHA no date]. Texas does not operate a state plan, so departments are not mandated to clear fire fighters for SCBA use. However, NIOSH investigators recommend that fire departments voluntarily provide clearance to enhance fire fighter health and safety.

Recommendation #7: Perform an annual physical ability evaluation (physical ability test) for fire fighters.

Discussion: Fire departments should determine the physical ability requirements for members who engage in emergency operations, as outlined in NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program* [NFPA 2013b, 2018b]. This helps ensure that fire fighters are physically capable of carrying out tasks required for structural fire fighting, and it is recommended that fire fighters be evaluated and certified on an annual basis [NFPA 2013b, 2018b].

Recommendation #8: Phase in a mandatory comprehensive fitness and wellness program to benefit all fire fighters.

Discussion: Guidance for fire department wellness/fitness programs to reduce cardiovascular risk factors and improve aerobic 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 and IAFC 2018; NFPA 2015b; Schneider 2010]. Worksite health promotion programs have demonstrated cost effectiveness by increasing productivity, reducing absenteeism, and decreasing the number of work-related injuries and lost workdays [Aldana 2001; Stein et al. 2000]. Health promotion programs in the fire service have improved cardiovascular risk factors and fitness levels, with mandatory programs showing the greatest benefit [Blevins et al. 2006; Dempsey et al. 2002; Womack et al. 2005].

The fire department has an outstanding voluntary wellness/fitness program. However, NIOSH recommends a formal, structured program to ensure all fire fighters receive the benefits of a health promotion program. In addition, during exercise time, fire fighters should be taken out of service to ensure uninterrupted participation.

References

Abriat A, Brosset C, Brégigeon M, Sagui E [2014]. Report of 182 cases of exertional heatstroke in the French Armed Forces. Mil Med *179*(3):309–314, https://dx.doi.org/10.7205/MILMED-D-13-00315.

AHA [2016]. Part 7: Adult advanced cardiovascular life support. 2015 American Heart Association Guidelines Update for cardiopulmonary resuscitation and emergency cardiovascular care. Dallas, TX: American Heart Association, https://eccguidelines.heart.org/index.php/circulation/cpr-ecc-guidelines-2/part-7-adult-advanced-cardiovascular-life-support/.

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, http://dx.doi.org/10.1249/MSS.0b013e31821ec.

Aldana SG [2001]. Financial impact of health promotion programs: a comprehensive review of the literature. Am J Health Promot *15*(5):296–320, http://dx.doi.org/10.4278/0890-1171-15.5.296.

ACSM, Armstrong LE, Casa DJ, Millard-Stafford M, Moran DS, Pyne SW, Roberts WO [2007]. American College of Sports Medicine position stand. Exertional heat illness during training and competition. Med Sci Sports Exerc *39*(3):556–572, PMID: 17473783.

Aoyagi Y, McLellan TM, Shephard RJ [1994]. Effects of training and acclimation on heat tolerance in exercising men wearing protective clothing. Eur J Appl Physiol Occup Physiol *68*(3):234–245, PMID: 8039520.

Armstrong LE, Casa DJ, Millard-Stafford D, Moran D, Pyne SW, Roberts WO [2007]. Exertional heat-related illnesses during training and competition - ACSM position stand. Med Sci Sports Exerc *39*(3):556–572, https://dx.doi.org/10.1249/MSS.0b013e31802fa199.

Armstrong LE, De Luca JP, Hubbard RW [1990]. Time course of recovery and heat acclimation ability of prior exertional heatstroke patients. Med Sci Sports Exerc *22*(1):36–48, PMID: 2406545.

Armstrong LE, Epstein Y [1999]. Fluid-electrolyte balance during labor and exercise: concepts and misconceptions. Int J Sport Nutr *9*(1):1–12, PMID: 10036337.

Armstrong LE, Maresh CM, Gabaree CV, Hoffman JR, Kavouras SA, Kenefick RW, Castellani JW, Ahlquist LE [1997]. Thermal and circulatory responses during exercise: effects of hypohydration, dehydration, and water intake. J Appl Physiol (1985) *82*(6):2028–2035, PMID: 9173973.

Benowitz NL [1990]. Clinical pharmacology of caffeine. Annu Rev Med *41*:277–288, PMID: 2184730.

Binkley HM, Beckett J, Casa DJ, Kleiner DM, Plummer PE [2002]. Exertional heat-related illnesses - National Athletic Trainers' Position Statement. J Athl Train *37*(3):329–343, PMID: 12937591.

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.

Bouchama A, Ollivier V, Roberts G, Al Mohanna F, de Prost D, Eldali A, Saussereau E, El-Sayed R, Chollet-Martin S [2005]. Experimental heatstroke in baboon: analysis of the systemic inflammatory response. Shock *24*(4):332–335, PMID: 16205317.

Carter R 3rd, Cheuvront SN, Williams JO, Kolka MA, Stephenson LA, Sawka MN [2005]. Epidemiology of hospitalizations and deaths from heat illness in soldiers. Med Sci Sports Exerc *37*(8):1338–1344, PMID: 16118581.

Casa DJ, DeMartini JK, Bergeron MF, Csillan D, Eichner ER, Lopez RM, Ferrara MS, Miller KC, O'Connor F, Sawka MN, Yeargin SW [2015]. National Athletic Trainers' Association position statement: exertional heat illnesses. J Athl Train *50*(9):986–1000, http://dx.doi.org/10.4085/1062-6050-50.9.07.

Cheuvront SN, Kenefick RW, Montain SJ, Sawka MN [2010]. Mechanisms of aerobic performance impairment with heat stress and dehydration. J Appl Physiol (1985), *109*(6):1989–1995, http://dx.doi.org/10.1152/japplphysiol.00367.2010.

Cleary M [2007]. Predisposing risk factors on susceptibility to exertional heat-related illness: clinical decision-making considerations. J Sport Rehabil *16*(3):204–214, PMID: 17923726.

CFR. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Crandall CG, Vongpatanasin W, Victor RG [2002]. Mechanism of cocaine-induced hyperthermia in humans. Ann Intern Med *136*(11):785–791, PMID: 12044126.

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.

DOD [2003]. Technical bulletin: heat stress control and heat casualty management. TB MED 507/AFPAM 48-152 (I). Washington, DC: Departments of the U.S. Army, Navy, and Air Force, http://www.apd.army.mil/epubs/DR_pubs/DR_a/pdf/web/tbmed507.pdf.

Drezner JA, Courson RW, Roberts WO, Mosesso VN Jr, Link MS, Maron BJ [2007]. Inter Association Task Force recommendations on emergency preparedness and management of sudden cardiac arrest in high school and college athletic programs: a consensus statement. Prehosp Emerg Care *11*(3):253–271, http://dx.doi.org/10.1080/10903120701204839.

Eberman LE, Cleary MA [2011]. Development of a heat-illness screening instrument using the Delphi panel technique. J Athl Train *46*(2):176–184, http://dx.doi.org/10.4085/1062-6050-46.2.176.

Eglin CM [2007]. Physiological responses to fire-fighting: Thermal and metabolic considerations. Journal of the human-environment System *10*(1):7–18, http://dx.doi.org/10.1618/jhes.10.7.

Eglin CM, Coles S, Tipton MJ [2004]. Physiological responses of fire-fighter instructors during training exercises. Ergonomics *47*(5):483–494, http://dx.doi.org/10.1080/00140130310001607568.

Epstein Y, Moran DS, Shapiro Y, Sohar E, Shemer J [1999]. Exertional heat stroke: a case series. Med Sci Sports Exerc *31*(2):224–228, PMID: 10063810.

FDA [2012]. Food - recalls, outbreaks and emergencies - safety alerts and advisories – energy “drinks” and supplements: investigations of adverse event reports. Silver Spring, MD: DHHS, FDA, http://wayback.archive-it.org/7993/20171114232636/https://www.fda.gov/Food/RecallsOutbreaksEmergencies/SafetyAlertsAdvisories/ucm328536.htm.

FDA [2016]. Questions and answers on dietary supplements. Silver Spring, MD: DHHS, FDA, https://www.fda.gov/food/dietarysupplements/usingdietarysupplements/ucm480069.htm.

Goforth CW, Kazman JB [2015]. Exertional heat stroke in navy and marine personnel: a hot topic. Crit Care Nurse *35*(1):52–59, http://dx.doi.org/10.4037/ccn2015257.

Haddams Volunteer Fire Department (VFD) [2013]. What’s it weigh? Firefighter gear, piece by piece. The Haddams Patch, January 1, https://patch.com/connecticut/thehaddams-killingworth/bp--whats-it-weigh-firefighter-gear-piece-by-piece.

IAFC [2016]. Healthcare provider's guide to firefighter physicals. Fairfax, VA: IAFC, http://www.fstaresearch.org/resource/?FstarId=11591.

IAFF, IAFC [2018]. The fire service joint labor management wellness/fitness initiative. 4th ed. Fairfax, VA: IAFC; Washington, DC: IAFF.

Jones JG [1991]. The physiological cost of wearing a disposable respirator. Am Ind Hyg Assoc J *52*(6):219–225, http://dx.doi.org/10.1080/15298669191364631.

Joy RJ, Goldman RF [1968]. A method of relating physiology and military performance. A study of some effects of vapor barrier clothing in a hot climate. Mil Med *133*(6):458-470, PMID: 4988425.

Kenney WL, Johnson JM [1992]. Control of skin blood flow during exercise. Med Sci Sports Exerc *24*(3):303–312, PMID: 1549024.

Leon LR, Bouchama A [2015]. Heat stroke. Compr Physiol *5*(2):611–647, http://dx.doi.org/10.1002/cphy.c140017.

Lopez R, Casa D, McDermott B, Stearns R, Armstrong L, Maresh C [2011]. Exertional heat stroke in the athletic setting: a review of the literature. Athletic Training and Sports Health Care *3*:189–200, http://dx.doi.org/10.3928/19425864-20101230-06.

Marzio L, Formica P, Fabiani F, LaPenna D, Vecchiett L, Cuccurullo F [1991]. Influence of physical activity on gastric emptying of liquids in normal human subjects. Am J Gastroenterol *86*(10):1433–1436, PMID: 1928033.

Maughan RJ, Griffin J [2003]. Caffeine ingestion and fluid balance: a review. J Hum Nutr Diet *16*(6):411–420, PMID: 19774754.

McArdle WD, McArdle FL, Klatch VL [2010]. Exercise physiology. In: McArdle WD, McArdle FL, Klatch VL, eds. Exercise physiology: nutrition, energy, and human performance. 7th ed. Philadelphia: Lippincott Williams and Wilkins.

McDermott BP, Casa DJ, Ganio MS, Lopez MR, Yeargin SW, Armstrong LE, Maresh CM [2009]. Acute whole-body cooling for exercise-induced hyperthermia: a systematic review. J Athl Train *44*(1):84–93, http://dx.doi.org/10.4085/1062-6050-44.1.84.

Montain SJ, Cheuvront SN [2008]. Fluid, electrolyte and carbohydrate requirements for exercise. In: Taylor NAS, Groeller H, eds. Physiological bases for human performance during work and exercise. Edinburgh: Churchill Livingstone Elsevier.

Moseley PL [1994]. Mechanisms of heat adaptation: thermotolerance and acclimatization. J Lab Clin Med *123*(1):48–52, PMID: 8288960.

NEHC [2007]. Prevention and treatment of heat and cold stress injuries. Technical Manual NEHC-TM-OEM 6260.6A. Portsmouth, VA: Navy Environmental Health Center, Bureau of Medicine and Surgery, http://www.med.navy.mil/sites/nmcphc/Documents/oem/Heat_and_Cold_final_June07.pdf.

NFPA [2012a]. Standard on live fire training evolutions. Quincy, MA: National Fire Protection Association. NFPA 1403.

NFPA [2012b]. Guide to building fire service training centers. Quincy, MA: National Fire Protection Association. NFPA 1402.

NFPA [2013a]. Standard on fire fighter professional qualifications. Quincy, MA: National Fire Protection Association. NFPA 1001.

NFPA [2013b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

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

NFPA [2014]. Standard for apparatus driver/operator professional qualifications. Quincy, MA: National Fire Protection Association. NFPA 1002.

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

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

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

NFPA [2018b]. Standard on fire department occupational safety and health program. Quincy, MA: National Fire Protection Association. NFPA 1500.

NHLBI [2005]. High blood cholesterol: what you need to know. Bethesda, MD: DHHS, National Institutes of Health, National Heart, Lung, and Blood Institute, https:/www.nhlbi.nih.gov/health/resources/heart/heart-cholesterol-hbc-what-html.

NIOSH [2015]. Evaluation of heat stress, heat strain, and rhabdomyolysis during structural fire fighter training. By Eisenberg J, Methner M, Dowell CH, Mueller C. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2012-0039-3242, https://www.cdc.gov/niosh/hhe/reports/pdfs/2012-0039-3242.pdf.

NIOSH [2016]. Criteria for a recommended standard: occupational exposure to heat and hot environments, revised criteria 2016. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2016-106, https://www.cdc.gov/niosh/docs/2016-106/pdfs/2016-106.pdf.

NOAA [2016]. Quality controlled local climatological data: (final). Hourly observations table, March 29-31, 2016. Silver Spring, MD: National Oceanic and Atmospheric Administration.

Nunneley SA, Reardon MJ [2002]. Prevention of heat-related illness. In: Wenger CB, ed. Medical aspects of harsh environments, Vol 1, Section I: Hot environments. Washington, DC: Office of The Surgeon General, Department of the Army, http://www.bordeninstitute.army.mil/published_volumes/harshEnv1/harshEnv1.html.

OSHA [no date]. State occupational safety and health plans. Washington, DC: Occupational Safety and Health Administration, http://www.osha.gov/dcsp/osp/index.html.

OSHA [2012]. OSHA respirator medical evaluation questionnaire. Washington, DC: OSHA, https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.134AppC.

Rav-Acha M, Hadad E, Epstein Y, Heled Y, Moran DS [2004]. Fatal exertional heat stroke: a case series. Am J Med Sci *328*(2):84–87, PMID: 15311166.

Roberts MF, Wenger CB [1979]. Control of skin circulation during exercise and heat stress. Med Sci Sports *11*(1):36–41, PMID: 481154.

Roti MW, Casa DJ, Pumerantz AC, Watson G, Judelson DA, Dias JC, Ruffin K, Armstrong LE [2006]. Thermoregulatory responses to exercise in the heat: chronic caffeine intake has no effect. Aviat Space Environ Med *77*(2):124–129, PMID: 16491580.

Sawka MN, Young AJ, Francesconi RP, Muza SR, Pandolf KB [1985]. Thermoregulatory and blood responses during exercise at graded hypohydration levels. J Appl Physiol *59*(5):1394–1401, PMID: 4066570.

Schneider EL [2010]. Firefighter fitness: a health and wellness guide. New York: Nova Science Publishers.

Serafin WE [1996]. Drugs used in the treatment of asthma. In: Hardman JG, Limbird LE, Molinoff PB, Ruddon RW, Gillman AG, eds. Goodman & Gilman's the pharmacologic basis of therapeutics. 9th ed. New York: McGraw-Hill.

Shapiro Y, Rosenthal T, Sohar E [1973]. Experimental heat-stroke: a model in dogs. Arch Int Med *131*:688–691, PMID: 4701378.

Shibolet S, Lancaster MC, Danon Y [1976]. Heat stroke: a review. Aviat Space Environ Med *47*(3):280–301, PMID: 769777.

Shiraishi S, Yokota H [2013]. Prevention and Treatment of Heat Illness. Journal of the Japan Medical Association *56*(3):174–178, http://www.med.or.jp/english/journal/pdf/2013_03/174_178.pdf.

Stein AD, Shakour SK, Zuidema RA [2000]. Financial incentives, participation in employer sponsored health promotion, and changes in employee health and productivity: HealthPlus health quotient program. J Occup Environ Med *42*(12):1148–1155, PMID: 11125677.

Stephenson LA, Wenger CB, O'Donovan BH, Nadel EL [1988]. Effect of gender, circadian period and sleep loss on thermal responses during exercise. In: Pandolf KB, Sawka MN, and Gonzalez RR, eds. Human Performance Physiology and Environmental Medicine at Terrestrial Extremes. Indianapolis, IN: Benchmark.

Tipton M, Pandolf K, Sawka M, Werner J, Taylor N [2008]. Physiological adaptation to hot and cold environments. In: Taylor N, Groeller H, eds. Physiological bases of human performance during work and exercise. Edinburgh: Churchill Livingstone Elsevier.

TDI [2016]. Firefighter fatality investigation. FFF FY 16-06. Austin, TX: Texas Department of Insurance, http://www.tdi.texas.gov/reports/fire/documents/fmloddhouston09.pdf.

TRADOC [2016]. Regulation 350-29: Prevention of heat and cold casualties. Fort Eustis, VA: U.S. Army Training and Doctrine Command, http://www.tradoc.army.mil/tpubs/regs/TR350-29.pdf.

USAPHC [2016]. Heat-related illness risk management slides for unit/installation training applications. Aberdeen Proving Ground, MD: U.S. Army Medical Department, U.S. Army Public Health Center, http://phc.amedd.army.mil/topics/discond/hipss/Pages/HeatInjuryPrevention.aspx.

Wallace RF, Kriebel D, Punnett L, Wegman DH, Wenger CB, Gardner JW, Gonzalez RR [2005]. The effects of continuous hot weather training on risk of exertional heat illness. Med Sci Sports Exerc *37*(1):84–90, PMID: 15632673.

Walter EJ, Carraretto M [2016]. The neurological and cognitive consequences of hyperthermia. Crit Care *20*(1):199, http://dx.doi.org/10.1186/s13054-016-1376-4.

White MK, Hodous TK [1987]. Reduced work tolerance associated with wearing protective clothing and respirators. Am Ind Hyg Assoc J *48*(4):304–310, PMID: 3591644.

Windle CM, Davies NJ [1996]. The effect of fitness on performance in a hot environment wearing normal clothing and when wearing protective clothing. In: Shapiro Y, Moran D, Epstein Y, eds. Environmental Ergonomics-recent progress and new frontiers. Tel Aviv: Freund Publishing House Ltd.

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

Wyndham CH [1973]. The physiology of exercise under heat stress. Annu Rev Physiol *35*:193–220, http://dx.doi.org/10.1146/annurev.ph.35.030173.001205.

Zahger D, Moses A, Weiss AT [1989]. Evidence of prolonged myocardial dysfunction in heat stroke. Chest *95*:1089–1091, PMID: 2707066.

Zhang Y, Coca A, Casa DJ, Antonio J, Green JM, Bishop PA [2015]. Caffeine and diuresis during rest and exercise: A meta-analysis. J Sci Med Sport *18*(5):569–574, http://dx.doi.org/10.1016/j.jsams.2014.07.017.

Investigator Information

This incident was jointly investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiac and Medical Line of Duty Deaths (LODD) Investigations Team in Cincinnati, Ohio, and the Trauma LODD Investigations Team and National Personal Protective Technology Laboratory located in Morgantown, West Virginia. 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. Mr. Steve Miles is a Safety and Occupational Health Specialist and a retired Battalion Chief of Safety with the Virginia Beach Fire Department and contributed to the report. Dr. Wendi Dick, Medical Officer/Team Lead for Cardiac and Medical LODD Investigations, provided medical consultation and contributed to the report. Mr. Jay Tarley is a Physical Scientist with the National Personal Protective Technology Laboratory and contributed to the report.

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 maze trailers. Below are links to other fatality investigations by NIOSH that involved this type of 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.

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Appendix A

Survival House Photographs and Diagrams

This appendix includes photographs of the survival house and various props. Diagrams of the interior layout of the survival house are also displayed.

Photo 1. Survival house exterior. ***(Courtesy of TX State Fire Marshal's Office.)***

Photo 2. Exterior props that the students use to build their skills before the survival house. ***(NIOSH photo.)***

Photo 3. Entanglement prop inside survival house. ***(NIOSH photo.)***

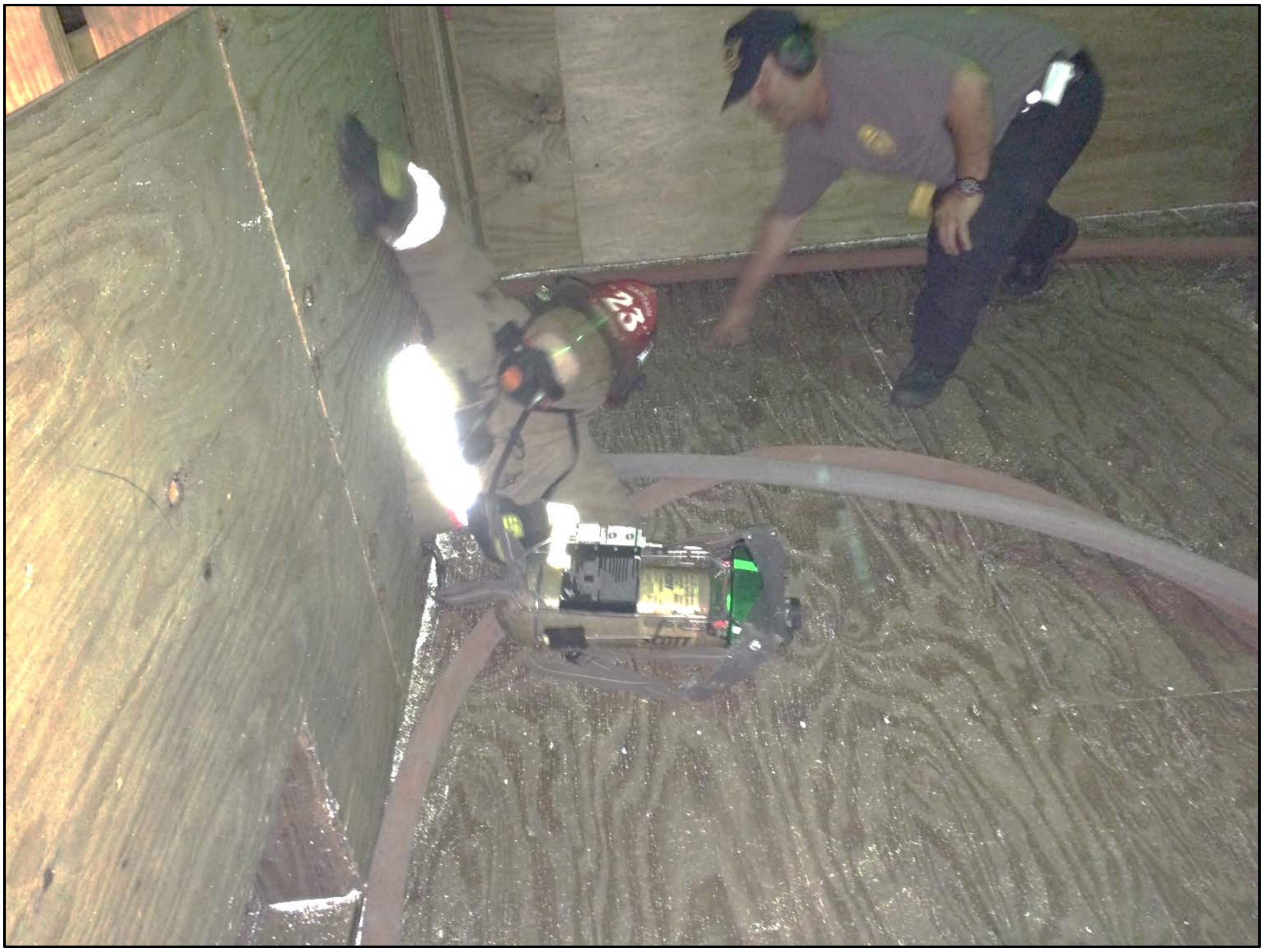

Photo 4. SCBA skills prop showing fire fighter profiling SCBA cylinder to pass through hole. ***(NIOSH photo.)***

Photo 5. SCBA skill house (instructors can monitor progress by openings in interior walls). ***(NIOSH photo.)***

Cadet Dies from Hyperthermia and Exertional Heat Stroke During Indoor SCBA Maze Training—Texas

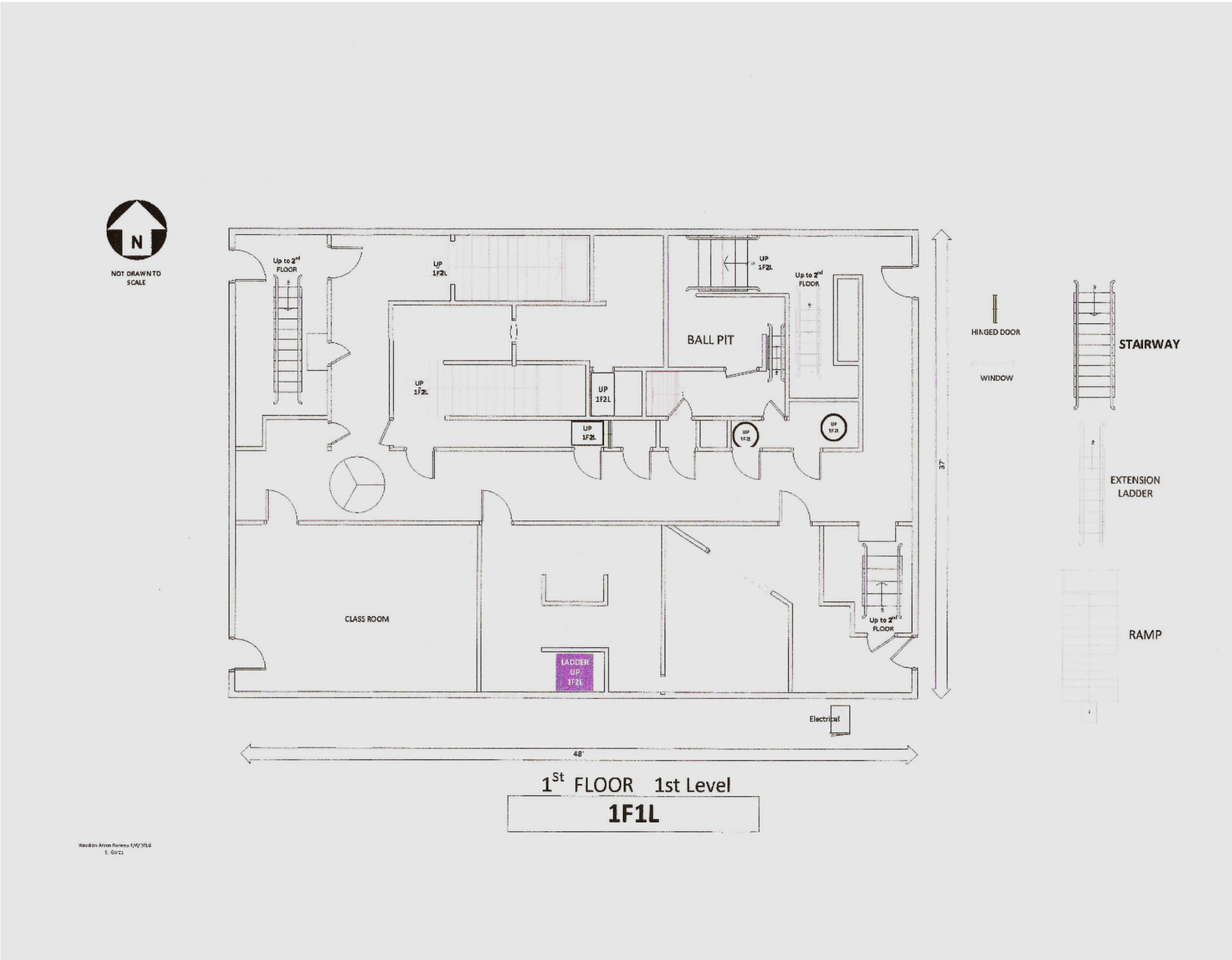

Diagram 1. Survival house. ***(Courtesy of fire department arson bureau.)***

Diagram 2. Survival house. ***(Courtesy of fire department arson bureau.)***

Cadet Dies from Hyperthermia and Exertional Heat Stroke During Indoor SCBA Maze Training—Texas

Diagram 3. Survival house. ***(Courtesy of fire department arson bureau.)***

Cadet Dies from Hyperthermia and Exertional Heat Stroke During Indoor SCBA Maze Training—Texas

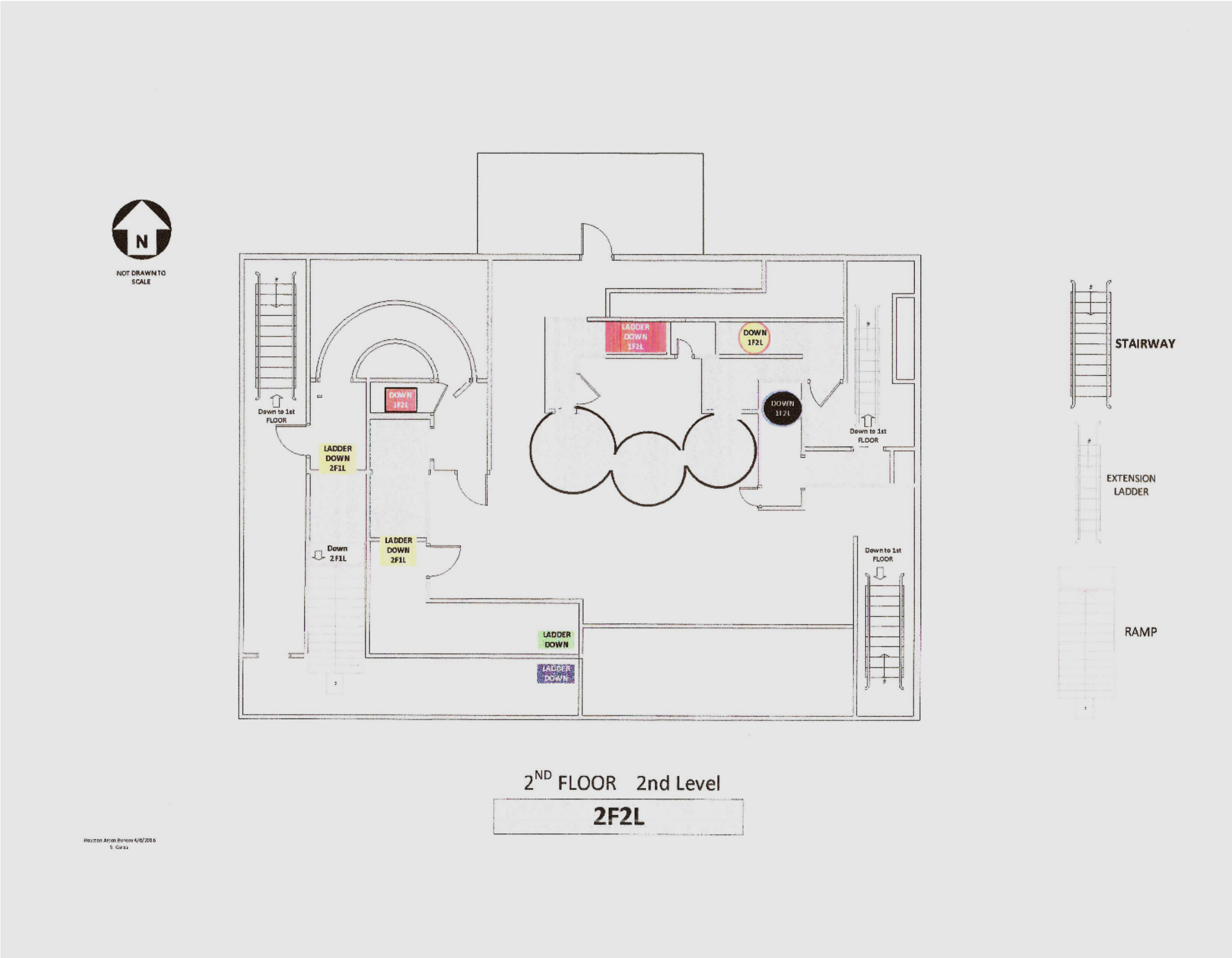

Diagram 4. Survival house. ***(Courtesy of fire department arson bureau.)***

Appendix B
Incident Timeline

This timeline provides the general sequence of events according to recorded radio transmissions. Times are approximate and were obtained from the state fire marshal's office report, witness interviews, and other available information. Some of the times have been rounded to the nearest minute. This timeline is not intended, nor should it be used, as a formal record of events.

Incident and Fireground Conditions	Time	Response and Fireground Operations
Cadet arrived at training facility	**0600**	Third and final day of survival training program
Instructional day began	**0700**	Survival house course
Cadet was inside survival house in the staging area in station dress, not wearing PPE	**0900**	Survival house was air conditioned; Cadet complained to another cadet that he was hot and sweaty and then moved to stand in front of air conditioning vent
Other cadets began the survival house course	**0912**	
Cadet was told to gear up in PPE and SCBA and prepare to enter course	**1015**	
Cadet donned PPE and SCBA and entered the course in the survival house (on-air)	**1025**	Cadet was the 8th student in the rotation on this evolution
	1025	Cadet was instructed to follow hoseline through the course and if he ran out of air, to disconnect the 2nd stage from the facepiece and continue the course
Cadet continued to advance through obstacles and entanglement props successfully	**1045–1100**	
Instructors had visual and verbal communications with the Cadet	**1045–1100**	Cadet responded correctly to instructors' prompts and was moving through the course well

Incident and Fireground Conditions	Time	Response and Fireground Operations
Cadet continued through course and at station 5 is questioned by instructor for orientation and fatigue	**1045–1100**	Instructor removed 3 students from the course at this station prior to seeing Cadet; Cadet responded appropriately to instructor's prompts and was breathing air from his SCBA
4 other cadets were on the course during this time; instructor opened an emergency access door to give instruction to one other cadet	**1045–1100**	Cadet started to move toward light from the open door and was told to stay on the course; Cadet was on air (2nd stage connected)
Cadet passed instructor at course exit; instructor pulled on hoseline indicating to Cadet that he was on the correct path	**1107–1115**	Cadet passed the exit point and moved up and down the wall area; instructor heard Cadet stop and a short time later heard Cadet's PASS alarm
Instructor called out to Cadet and receiving no response entered the course through a trap door, alerted other instructors, and called a Mayday Another instructor entered the course to assist	**1107–1115**	
Cadet was removed from course and his PPE and SCBA removed Cadet is breathless and pulseless	**1107–1115**	CPR was initiated, AED was applied, and airway was placed
On-site FD ALS rescue unit was summoned	**1115–1116**	ALS administer patient care; Cadet was in asystole with a rectal temperature of 108 degrees F. Active cooling measures were initiated with cold packs placed in groin and arm pits and cooled IV fluids
Cadet was transported to hospital	**1136**	Cadet's temperature was 109 degrees
Medic unit with Cadet arrived at hospital	**1151**	Patient care was transferred to emergency department staff; ALS, cooling measures, and CPR were continued
	1248	Cadet was pronounced dead

Appendix C

Candidate Physical Ability Test (CPAT)

The CPAT consists of two separate components. The first component is a series of tasks designed to assess important physical abilities necessary for effective job performance as a fire fighter. The second component is a 1.5-mile run. The following section describes both components of the physical ability test and offers information to assist the candidate in preparing.

Component 1: Job Simulation Tasks

The first component of the test contains five job-simulation events that will be timed in a continuous series. These events include:

- Ladder Raise
- Stair Climb With Equipment
- Hoseline Hoist
- Equipment Carry
- Victim Rescue (dummy drag)

The following guidelines apply to this component of the CPAT:

- Applicants must wear a self-contained breathing apparatus (SCBA), excluding the facepiece and low-pressure hose, for all elements of the job simulation component. The SCBA weighs approximately 20 pounds.
- Applicants are strongly encouraged to wear athletic shoes (sneakers) and appropriate clothing for physically demanding work. You will be performing physical acts that demonstrate strength, agility, and endurance, and it is important to be outfitted in attire that does not hinder your performance. During the CPAT, you may get dirty and/or wet from maneuvering through the exercises. Plan your dress accordingly.
- Protective gloves are optional and it is the candidate's choice whether or not to use gloves. You may bring your own gloves, kneepads, etc. to use; however, the testing authority reserves the right to inspect all equipment, and to disallow equipment, to ensure that its use does not affect the fair and impartial administration of the CPAT.
- All five elements of this component of the CPAT will be timed in a series. The test has a cutoff time and failure to complete the course in the allowed time will result in disqualification.
- You must not run during the test. Running is not permitted on a working fireground, and it will not be allowed during this test. Failure to heed a first warning not to run may result in disqualification. Running is defined as any time both feet are off the ground at the same time while you are advancing on the course. You may move as fast as you like, while remaining safe on the stair climb stations, as it is not technically possible to run during these components.

- You should hit every stair going up and coming down while climbing the stairs. You may move as quickly as you like and are encouraged to use the handrails as needed.
- Test monitors will be assigned to time you while on the course. It is acceptable to ask the test monitor questions concerning course rules and layout prior to beginning the course and while on the course.
- You will be allowed as much time as needed to complete each individual component of the CPAT within the maximum allotted time. Should you perform one of the components incorrectly, the test monitor will guide you as to how to correct your actions or to perform the component again. Pay careful attention to the instruction of the test monitor and ask for clarification when needed.
- Unnecessarily dropping, throwing, or other intentional misuse of any of the testing props will be grounds to disqualify a candidate.

The following provides a description and preparation information regarding each of the five events contained in the first component of the CPAT.

1. Ladder Raise. The candidate will raise the fly section of a 24-foot extension ladder using the rope (halyard). The ladder is secured to the rails of the tower staircase. The candidate will use a hand-over-hand technique to extend the fly section of the ladder until the ladder is fully extended. The candidate will then lower the fly section down using a hand-under-hand technique. If the candidate loses control of the halyard (e.g., the rope slips through hands), he/she will be required to perform the event again. While raising and lowering the ladder, the candidate’s feet must remain in a 3-foot-by-3-foot box that is painted on the ground.

Preparation: To simulate the ladder raise exercise, you can tie a rope securely to a weighted bag and place the rope over a sturdy horizontal bar that is eight to ten feet above the ground. Then you can use the same movements as you would in the ladder raise to bring the weight to the top of the bar and slowly lower it back to the ground.

2. Stair Climb. The candidate will climb up to and back down from the 7th floor of the training tower (6 flights of stairs) while carrying a bundled section of 2½-inch hoseline that weighs 35 pounds. Before entering the tower, the candidate will pick up the bundled hose pack. The candidate must carry this hose pack without dragging it. The candidate should hit every stair going up and coming back down the staircase. When the candidate reaches the 7th floor, he/she will place his/her feet on the landing and then turn around and descend the stairs. The candidate may use the handrails and may move as fast as he/she chooses on the stairs. Once the candidate exits the tower, he/she should set the hose pack on the ground.

Preparation: This station assesses muscular and cardiovascular endurance. You may practice for this station by ascending and descending stairs while carrying approximately 55 pounds of weight (SCBA plus hose pack).

3. Hose Hoist. The candidate will ascend to the third floor of an outdoor staircase, use a rope to hoist a rolled-up section of hoseline up to and back down from the third floor, and then descend the staircase. If the candidate loses control of the rope (e.g., the rope slips through hands), he/she will be required to perform the event again. While raising and lowering and hose roll, the candidate’s feet must remain in a box that is painted on the ground on the 3rd floor landing.

Preparation: To simulate the hose hoist, you can tie a rope securely to a weighted bag and place the rope over a sturdy horizontal bar that is eight to ten feet above the ground. Then you can use the same movements as you would to reel in a load attached to the rope. The weight of the hoseline is approximately 35 pounds.

4. Equipment Carry. The candidate will carry a box weighing 75 pounds for a distance of 100 feet. The candidate will pick up the box off a 2-foot platform, carry the box for 50 feet around a cone and back to the starting location, and place the box on top of a 3-foot platform. The weighted box simulates the weight of a hydraulic power plant. You may set the box down at any time to rest, but may not drag or push the box – it must be carried.

Preparation: This station assesses core body strength, grip strength, and overall cardiovascular endurance. You may prepare for this event by carrying a 75-pound object for a distance of 100 feet.

5. Victim Rescue (Dummy Drag). The candidate will drag a human form dummy weighing 165 pounds (weight of dummy and clothing) for 25 feet, around a barrel/cone and then back across the starting point for a total distance of 50 feet. The candidate will drag the dummy using the pull harness attached to the dummy or by placing his/her elbows under the armpits of the dummy. In order to complete this station, the candidate and the dummy must both completely cross the finish line.

Preparation: This station assesses lower body strength and endurance. You may prepare for this event by dragging a weighted object using a rope.

The five simulation events are timed in a series. Any candidate that completes the course in 6 minutes and 40 seconds (6:40) or less will pass this first component of the CPAT.

Component 2: 1.5-Mile Run

Assuming the candidate successfully completed the first component of the CPAT, he/she will be afforded a rest period of approximately 15 to 20 minutes. After this time, the candidate will run 1.5 miles. The 1.5-mile run must be completed in 15 minutes (15:00) or less to pass the CPAT.

The 1.5-mile run is cardiovascularly demanding. In order to prepare for this component, you should run 1.5 miles multiple times and time yourself to ensure that you can achieve the necessary time.

Appendix D

Academy Candidate Physical Ability Tests (PAT)

Grading

Trainees must obtain a minimum score of 70% on each Physical Ability Test. Failure to obtain a 70% will result in a retest. If upon retest the trainee passes that portion of the Physical Ability Test, the trainee will be given the minimum passing score (70%) for that portion of the test. The total number of Physical Ability Tests will be averaged for a final grade standing. The Training Officer will provide specific information regarding each portion of the Physical Ability Tests.

PAT #1 will be given approximately one month into the training program and will consist of:

1. 1.5-mile run under 13:07 for the minimum passing score of 70 - scores will then be prorated with 8:30 considered to be 100.
2. Sit-ups (1 minute) - The minimum number is 25 for a grade of 70 - with one-half a point awarded for each additional sit-up.
3. Push-ups (1 minute) - The minimum number is 25 for a grade of 70 - with one-half a point awarded for each additional push-up.
4. Pull-ups (1 minute) - The minimum number is 1 for a grade of 70 - with one-half a point awarded for each additional pull-up.

PAT #2 will be given approximately two months after PAT #1: (1 month for Fast Track)

1. 1.5-mile run under 12:15 for the minimum passing score of 70 - scores will then be prorated with 8:30 considered to be 100.
2. Sit-ups (1 minute) - The minimum number is 30 for a grade of 70 - with one-half a point awarded for each additional sit-up.
3. Push-ups (1 minute) - The minimum number is 30 for a grade of 70 - with one-half a point awarded for each additional push-up.
4. Pull-ups (1 minute) - The minimum number is 3 for a grade of 70 - with one-half a point awarded for each additional pull-up.

PAT #3 will be given approximately two months after PAT #2:

1. 1.5-mile run under 11:30 for the minimum passing score of 70 - scores will then be prorated with 8:30 considered to be 100.
2. Sit-ups (1 minute) - The minimum number is 35 for a grade of 70 - with one-half a point awarded for each additional sit-up.
3. Push-ups (1 minute) - The minimum number is 35 for a grade of 70 - with one-half a point awarded for each additional push-up.

4. Pull-ups (1 minute) - The minimum number is 5 for a grade of 70 - with one-half a point awarded for each additional pull-up.

PAT #4 will be given approximately two months after PAT #3:

1. 1.5-mile run under 11:30 for the minimum passing score of 70 - scores will then be prorated with 8:30 considered to be 100.
2. Sit-ups (1 minute) - The minimum number is 35 for a grade of 70 - with one-half a point awarded for each additional sit-up.
3. Push-ups (1 minute) - The minimum number is 35 for a grade of 70 - with one-half a point awarded for each additional push-up.
4. Pull-ups (1 minute) - The minimum number is 5 for a grade of 70 - with one-half a point awarded for each additional pull-up.

NOTE: All trainees may be subjected to additional PAT tests following PAT #4 during their tenure at the academy.

Appendix E

Evaluation of a Self-Contained Breathing Apparatus for Potential Contribution to a Fatal Event in the Fire Service

NIOSH Task Number 20842

NOTE: The full report, including Appendices I–III, is available at https://www.cdc.gov/niosh/npptl/ppe-fireservice/completedrpts.html.

Background

As part of the ***National Institute for Occupational Safety and Health (NIOSH) Fire Fighter Fatality Investigation and Prevention Program (FFFIPP)***, the National Personal Protective Technology Laboratory (NPPTL) agreed to examine and evaluate a self-contained breathing apparatus (SCBA) unit.

This SCBA status investigation was assigned NIOSH Task Number 20842. The NIOSH Division of Safety Research (NIOSH/DSR) and the Fire Department were advised that NIOSH/NPPTL would provide a written report of the inspections and any applicable test results.

The SCBA unit was shipped to the NIOSH/NPPTL facility in Morgantown, West Virginia. The unit was received on May 13, 2016, and placed in secured storage.

SCBA Inspection

The unit was inspected on May 13, 2016 by staff from the Morgantown Testing Team (MTT), NPPTL (Mr. Jeremy Gouzd, Fellow, and Ms. Karis Kline, Contractor). The SCBA was identified as the Fire Department SCBA and was extensively examined, component by component, in the condition received to determine how well the unit conformed to the NIOSH-approved configuration. The unit was identified as the Scott® Safety Company model Air-Pak® 4.5, 30 minute, 4500 psi unit, NIOSH approval number TC-13F-212CBRN. The visual inspection process was documented photographically.

The cylinder was included and gauges showed that the tank was empty. No facepiece was included with the unit. The following components were included with the SCBA unit and were thoroughly inspected: mask mounted regulator (MMR) with Heads Up Display (HUD), low pressure line, pressure reducer assembly, high pressure line and cylinder attachment, console assembly PASS (personal alert safety system), PASS control module, backframe assembly, straps and buckles, cylinder and valve assembly. The NFPA approval label was present and readable. The SCBA unit exhibited signs of normal wear and tear and did not show any signs of heat damage. All components were in fair to good condition. Following inspection, the unit was returned to secured storage until testing was performed.

The complete SCBA inspection is summarized in **Appendix I** of the full report. The condition of each major component of the SCBA that was photographed with a digital camera is contained in **Appendix III** of the full report.

SCBA Testing

Testing of the SCBA unit began on August 5, 2016. The purpose of the testing was to determine how well the SCBA conformed to the approval performance requirements of Title 42, *Code of Federal Regulations*, Part 84 (42 CFR 84). Further testing was conducted to provide an indication of the SCBA's conformance to the National Fire Protection Association (NFPA) Airflow Performance requirements of NFPA 1981, *Standard on Open-Circuit Self-Contained Breathing Apparatus for the Fire Service*, 1997 Edition.

NIOSH SCBA Certification Tests (in accordance with the performance requirements of 42 CFR 84):

1. Positive Pressure Test [§ 84.70(a)(2)(ii)]
2. Rated Service Time Test (duration) [§ 84.95]
3. Static Pressure Test [§ 84.91(d)]
4. Gas Flow Test [§ 84.93]
5. Exhalation Resistance Test [§ 84.91(c)]
6. Remaining Service Life Indicator Test (low-air alarm) [§ 84.83(f)]

NFPA Tests (in accordance with NFPA 1981, 1997 Edition):

7. Airflow Performance Test [Chapter 5, 5-1.1]

A stock Scott® facepiece was used for testing as no facepiece was provided. The SCBA unit passed all NIOSH SCBA certification tests. The measured service time (adjusted to correspond with the recorded breathing cycles) was more than the rated service time of 45 minutes. The SCBA unit passed the NFPA airflow performance test. The PASS unit, HUD, and alarm systems were all functional. The SCBA unit was returned to storage pending return to the Fire Department.

Appendix II of the full report (online) contains the complete NIOSH test report for the SCBA. **Tables ONE and TWO** summarize the NIOSH and NFPA test results.

Summary and Conclusions

As part of the NIOSH FFFIPP, the NPPTL evaluated an SCBA unit submitted by the Fire Department. The SCBA unit was received at NPPTL on May 13, 2016 and inspected the same day. The unit was identified as a Scott® Safety model Air-Pak® 4.5, 4500 psi, 30-minute, SCBA (NIOSH approval number, TC-13F-212CBRN). A cylinder was included, and gauges showed the tank was empty. A facepiece was not provided with the unit. Inspection of the SCBA components showed normal signs of wear and tear, no signs of heat damage, and the overall condition of the SCBA was good. A stock Scott® facepiece was used for the testing portion of the evaluation, which began on August 5, 2016.

Results from testing showed that the SCBA unit passed all of the NIOSH SCBA certification tests as well as the NFPA airflow performance test. If the unit is to be placed back in service, the SCBA must be repaired, tested, cleaned, and any damaged components replaced and inspected by a qualified service technician, including such testing and other maintenance activities as prescribed by the schedule from the SCBA manufacturer.

Appendix F
Autopsy Findings

Cause of Death:
Hyperthermia and Dehydration (based on autopsy, history, and circumstances of death)

Autopsy findings:

a. Vitreous humor post-mortem chemistry results "consistent with dehydration"
   - Sodium 151 milliequivalents per liter
   - Vitreous urea nitrogen (VUN) 20 mg/dL

   Normal range: sodium 135–150 mEq/L; VUN 8–20 mg/dL [NMS Labs 2018]

b. Other vitreous humor results: creatinine 0.6 mg/dL, chloride 113 mEq/L, potassium 11.9 mEq/L, glucose 11 mg/dL, and no ketones (all within normal ranges [NMS Lab 2018])

c. Cardiomegaly (heart weight 450 grams)

d. Left ventricular hypertrophy (wall thickness 1.7 centimeters)

e. Microscopic exam of heart:
   - Myocyte hypertrophy; only minimal interstitial and perivascular fibrosis
   - Multifocal contraction band necrosis

f. Coronary artery atherosclerosis
   - 40% to 50% stenosis of left main artery
   - 10% to 20% stenosis of left anterior descending artery

g. No evidence of infection, sepsis, or rhabdomyolysis detected on microscopic exam

h. Bladder contained 35 milliliters (cc) of clear, yellow urine

i. No evidence of pulmonary embolus (blood clot in the lung arteries)

j. Carboxyhemoglobin level < 5% (not elevated)

k. Normal hemoglobin and thyroid studies

l. Toxicology testing was negative.

Medical co-author's discussion:

The predicted heart weight for males of the same body weight as the Cadet is 331 grams (251–437 grams), according to autopsy studies by Kitzman et al. [1988]. The normal thickness of the wall of the left ventricle is in the range of 1.07 to 1.39 centimeters (average 1.23 centimeters) [Kitzman et al. 1988]. The findings of a heavier than predicted heart, thicker than normal left ventricle wall, and enlarged ventricles may be consistent with physiologic "remodeling" that can develop in response to intense and prolonged endurance training [Weiner and Baggish 2012]. These changes are often referred to as "athlete's heart."

It is not uncommon to find coronary atherosclerosis at the time of autopsy in adults whose deaths were not due to heart disease. (Nearly 1 in 4 military members in their 30s who died from combat or injuries were found to have some degree of atherosclerosis at autopsy [Webber et al. 2012]). Stable coronary atherosclerosis lesions that cause < 50% obstruction in an artery are very unlikely to be of clinical consequence [Knudtson 2014].

Regarding hyperthermia/heat stress, autopsy findings from these deaths may be absent or nonspecific, particularly for victims who succumb shortly after severe hyperthermia develops [Lifschultz and Donoghue 1998; Nixdorf-Miller et al. 2006]. In heat stroke victims who survive for hours, post-mortem findings are not consistent but may include evidence of rhabdomyolysis, acute kidney damage, liver failure, and other pathological changes.

REFERENCES

Kitzman DW, Scholz DG, Hagen PT, Ilstrup DM, Edwards WD [1988]. Age-related changes in normal human hearts during the first 10 decades of life. Part II (maturity): a quantitative anatomic study of 765 specimens from subjects 20 to 99 years old. Mayo Clin Proc *63*(2):137–146, PMID: 3276974.

Knudtson M [2014]. Coronary scoring systems: a historical perspective, March 2014. Alberta, Canada: Alberta provincial project for outcomes assessment in coronary heart disease (APPROACH) https://www.approach.org/pdfs/tutorials/History_of_Coronary_Scoring_March2014.pdf.

Lifschultz BD, Donoghue ER [1998]. Forensic pathology of heat-and cold-related injuries. Clin Lab Med *18*(1):77–90, PMID: 9523065.

Nixdorf-Miller A, Hunsaker DM, Hunsaker JC 3rd [2006]. Hypothermia and hyperthermia medicolegal investigation of morbidity and mortality from exposure to environmental temperature extremes. Arch Pathol Lab Med *130*(9):1297–1304, PMID: 16948514.

NMS Labs [2018]. Test catalog. Willow Grove, PA: NMS Labs, http://www.nmslabs.com/test-catalog.

Webber BJ, Seguin PG, Burnett DG, Clark LL, Otto JL [2012]. Prevalence of and risk factors for autopsy-determined atherosclerosis among US service members, 2001-2011. JAMA *308*(24):2577–2583, http://dx.doi.org/doi:10.1001/jama.2012.70830.

Weiner RB, Baggish AL [2012]. Exercise-induced cardiac remodeling. Progress in Cardiovascular Diseases *54*(5):380–386, http://dx.doi.org/10.1016/j.pcad.2012.01.006.