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Death in the line of duty...

NIOSH Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation June 21, 2016

Wildland Fire Fighter Dies From Hyperthermia During Pack Test—Arizona

Executive Summary

On June 6, 2015, a 30-year-old male seasonal wildland fire fighter (FF) was completing the arduous duty work capacity test ("pack test"). After walking 3 miles with a 45-pound pack in 40 minutes, he collapsed about 100 yards before the finish line. Crew members assisted him to his feet and helped him cross the finish line. A standby emergency medical technician treated him for heat exposure. He became unresponsive and cardiopulmonary resuscitation (CPR) was begun. The emergency medical technician notified Dispatch and departed with the FF in the ambulance. A paramedic unit met the ambulance en route to the hospital's emergency department (ED). The FF was transferred to the paramedic unit where they provided advanced life support. They did cardiac monitoring and placed an intraosseous line for resuscitative medications. They continued CPR for about 14 minutes. The FF's clinical status did not improve. Medical control was notified and the FF was pronounced dead en route to the ED.

The Medical Examiner completing the death certificate listed "hyperthermia" as the cause of death. The Forensic Pathologist completed the autopsy report. It listed "hyperthermia and probable dehydration due to physical exertion" as the cause of death.

Key Recommendations

- *Provide preplacement and annual medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to identify fire fighters at increased risk for coronary heart disease (CHD)*
- *Ensure ice water immersion therapy is rapidly available for training involving heavy physical exertion*
- *Ensure fire fighters are acclimatized prior to the pack test*

Wildland Fire Fighter Dies From Hyperthermia During Pack Test—Arizona

Introduction

On June 6, 2015, a 30-year-old male seasonal wildland FF died from hyperthermia during his arduous duty pack test. NIOSH was notified of this fatality on June 9, 2015, by the U.S. Fire Administration. NIOSH contacted the affected agency on June 9, 2015, to gather additional information and on November 3, 2015, to initiate the investigation. On November 9, 2015, a safety and occupational health specialist from the NIOSH Fire Fighter Fatality Prevention and Investigation Program conducted an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Wildlife Refuge Manager
- Fire Management Officer
- Agency representatives
- Fire Camp representatives
- County Forensic Pathologist
- FF's spouse

NIOSH personnel reviewed the following documents:
- Emergency medical service (ambulance) report
- Death certificate
- Autopsy report
- Agency medical evaluation records
- Primary care physician records
- Death certificate
- Autopsy report

Investigation

On May 17, 2015, the FF began classroom and practical training at a fire camp in Colorado (7,083 feet elevation). On May 20, 2015, he was examined by a contract physician and cleared for "arduous wildland fire fighter duties." On May 21, 2015, the FF returned home to Virginia for a family emergency. He rejoined his training team in Arizona (their initial duty assignment) on June 2, 2015. The FF performed adminstrative duties (completed in-processing paperwork, obtained personal protective equipment, and received safety briefings) on June 2 and June 3, 2015.

On June 4, 2015, the FF performed the pack test with 10 crewmembers. The test requires participants wearing a 45-pound weighted vest to walk 3 miles in 45 minutes. The weather conditions at about 0700 hours included a temperature of 74 degrees Fahrenheit and a humidity level of 12 percent

[NOAA 2015a]. The daily highs reached 93 degrees Fahrenheit and 14 percent relative humidity [NOAA 2015a]. Finishing the test in 55 minutes and 10 seconds, the FF did not pass. He was scheduled to repeat the test on June 6.

On June 5, 2015, the FF began work at 0700 hours. Working with his team, he cleared brush. The weather conditions at about 0700 hours included a temperature of 75 degrees Fahrenheit and a humidity level of 48 percent [NOAA 2015b]. The daily highs reached 95 degrees Fahrenheit and 17 percent relative humidity level [NOAA 2015b]. Work ended at 1630 hours and the crew departed the work site. The FF showed no adverse effects related to the heat. After dinner and during the evening, the FF consumed about three beers.

On June 6, 2015, the FF arrived at about 0700 hours for his second pack test. A project leader, seven crewmembers, and an ambulance staffed with one emergency medical technician were on site. Weather conditions included a temperature of 78 degrees Fahrenheit and a humidity level of 31 percent [NOAA 2015c]. The FF and his crewmembers did stretching and warmup exercises until the test began at 0715 hours. All crewmembers hydrated prior to the test but none carried or drank water during the test. The FF exhibited no unusual symptoms while walking and had no unusual complaints. At approximately the 40-minute mark (0800 hours), the FF collapsed to his knees without warning. He was about 100 yards from the finish line. Crewmembers assisted him to his feet but he was unable to stand without support. Crewmembers assisted him across the finish line and then to shade where cold packs were applied.

He was placed onto a stretcher at 0810 hours, Dispatch was notified, and a paramedic was requested to meet the ambulance enroute because the FF became unresponsive. His stretcher was loaded into the ambulance. His pulse was weak and thready. His temperature was not taken. He became pulseless and CPR was begun. An oropharyngeal airway was placed, and oxygen administered via bag-valve-mask. Automated external defibrillator leads were placed, but no shock was advised and CPR continued. The ambulance departed the scene at 0815 hours and met the paramedic unit at 0830 hours. An intraosseous line was placed and cardiac resuscitation medications were administered. His clinical status did not improve. A cardiac monitor revealed asystole (no heart beat). Despite being given three additional rounds of intraosseous medications he remained in asystole. Cardiac resuscitation efforts continued until 0925 hours when the paramedic notified the hospital's ED physician of the FF's clinical status. The FF was pronounced dead and resuscitation efforts were discontinued.

Medical Findings

The death certificate, completed by the Medical Examiner, listed "hyperthermia" as the cause of death. The autopsy report, completed by the Forensic Pathologist, listed "hyperthermia and probable dehydration due to physical exertion" as the cause of death. The vitreous (eye fluid) chemistries were within normal limits. Specific autopsy findings are listed in Appendix A.

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The FF had the following medical conditions:

- Depression – first diagnosed in 2014 and began prescription anti-depression medications. The last time he saw his physician was in October 2014. He had stopped the medication prior to this incident.
- Obesity – The FF was 70 inches tall and weighed 220 pounds in May 2015, giving him a body mass index of 31.6 kilograms per meters squared [CDC 2015].

In addition, on autopsy, he was found to have left ventricular hypertrophy.

Agency

At the time of the NIOSH investigation, the non-profit Agency that hired the FF trained and engaged teams of military veterans in wildland fire mitigation. Team members work together for 6 months in Arizona, New Mexico, and Texas and then return home. The FF attended wildland fire fighter training in Colorado before his Arizona assignment. The Arizona location is comprised of 117,000 acres of wildland. Fire mitigation is provided by 12 full-time and 4 career seasonal wildland fire fighters housed in two fire stations. Contracts between the agencies allow certified wildland fire fighters (non-federal employees) to work at federal wildland locations.

Employment and Training

The FF's employing Agency requires applicants to:

- possess an honorable discharge or general discharge (under honorable conditions)
- possess a valid driver's license
- pass a criminal background and motor vehicle check
- pass the U.S. Forest Service Pack Test at the arduous level (3-mile hike with a 45-pound pack in 45 minutes)
- have the ability to hike long distances with a heavy pack and remain composed under pressure while serving in rugged terrain
- have comfort and ability with a chainsaw and other hand tools,
- have comfort and ability with living and serving with veterans from all service branches
- pass classroom, practical, and physical fitness training.

Typically the new member completes the pack test at fire camp. In this incident, the FF had a family emergency and left early. As a result, he did the pack test at his assigned location in Arizona.

Medical Evaluations

Preplacement and Periodic Medical Evaluations

Applicants must submit a medical questionnaire and list no pre-existing conditions that would preclude them from work. At the next level of training (fire camp), trainees must pass a preplacement medical evaluation which includes the following:

▪ Complete medical history

- Physical examination (including vital signs)
- Whisper test for hearing
- Snellen vision screen

The evaluation is performed by a contract physician who makes a determination regarding medical clearance for fire fighting duties (including the arduous duty pack test). The physician forwards this decision to the Agency. The FF was cleared for arduous duty in May 2015.

Periodic medical evaluations are not required by the Agency.

Fitness/Wellness Programs

The Agency has a voluntary fitness program. Fire fighters are encouraged to maintain physical fitness due to the demands of wildland fire fighting. An arduous duty pack test is required annually to fight wildfires on federal property.

Discussion

Although the FF was found at autopsy to have left ventricular hypertrophy, which is known to increase the risk for sudden cardiac death [Levy et al. 1990], hyperthermia and heatstroke are the likely reasons for this FF's death.

Hyperthermia/Heat-Related Illness (HRI)/Heatstroke

Hyperthermia is characterized by an uncontrolled increase in body temperature that exceeds the body's ability to lose heat [CDC 2006]. Exertional hyperthermia is defined as a core body temperature above 104 degrees Fahrenheit during activity [Armstrong et al. 2007]. The FF's temperature was not measured at the scene or en route to the hospital. Based on the clinical scenario, however, the forensic pathologist listed hyperthermia as the cause of death.

Heat sources for hyperthermia are external to the body (environmental) and internal to the body (metabolic heat produced during physical exertion). *Heat stress* is the sum of the heat generated from the body plus heat gained from the environment minus heat lost due to evaporation [ACGIH 2011; NIOSH 2016]. Mild to moderate heat stress may cause discomfort, but is not harmful to health. As heat stress increases it causes *heat strain*, which is a physiologic response of the body. Heat strain manifests as increases in heart rate and core body temperature. As heat strain approaches human tolerance limits and core body temperature rises, the risk of heat-related illness (HRI) increases.

When individuals with hyperthermia become symptomatic, the condition is known as HRI. HRI represents a wide spectrum of conditions typically ranging in severity from skin rashes and heat cramps, to heat exhaustion, heat syncope, and heatstroke. The milder HRI conditions (rash and cramps) do not necessarily precede the more severe conditions. Heatstroke, the most severe form of HRI, is a life-threatening condition. It is defined as a core body temperature greater than 104 degrees Fahrenheit with central nervous system disturbances and multiple organ system failure [Donoghue et al. 1997;

Armstrong et al. 2007]. In the general population, heatstroke has a mortality rate ranging from 33%-80% [Vicario et al. 1986; Seraj 1992].

Rapid core body temperature reduction is the most effective treatment for exertional heatstroke. Its use has resulted in lower exertional heatstroke mortality rates [Costrini 1990; Bouchama et al. 2007; McDermott et al. 2009]. Cold/ice water immersion is the best method, and is endorsed by the American College of Sports Medicine and the National Athletic Trainers' Association [Binkley et al. 2002; Armstrong et al. 2007]. In this incident, cold/ice water immersion was not available on-scene. Although shade and cold packs were applied by EMS personnel, these treatments are not very effective in reducing core body temperature [Binkley et al. 2002; Armstrong et al. 2007]. Addionally, the advanced life support measures taken in the field (i.e., fluids, cardiac monitoring, and oxygen) would not have rapidly lowered the FF's core body temperature. Had cold/ice water immersion been available, the FF's core temperature could have been reduced sooner, improving his prognosis.

Personal Risk Factors for HRI and Exertional Heatstroke

Personal risk factors for exertional heatstroke include increased age, obesity, poor physical fitness, a previous history of exertional heatstroke, and various medical conditions (e.g., heart disease, renal disease, diabetes mellitus, skin conditions, sunburn, sweat gland dysfunction, viral illness, diarrhea, etc.). On the basis of body mass index, the FF would be considered obese. Some medications can increase the risk of HRI, including: 1) drugs that reduce sweating such as antihistamines (e.g., Benadryl®); 2) drugs that reduce cutaneous blood flow (e.g., stimulants such as cocaine, amphetamines, ephedrine, pseudoephedrine, caffeine, energy drinks, dietary supplements, theophylline); 3) drugs that can cause dehydration (e.g., diuretics); and 4) drugs that can inhibit central thermoregulation (e.g., neuroleptics and tricyclic antidepressants) [Armstrong et al. 2007]. There is no evidence the FF was taking any of these medications. Although the autopsy results were positive for alcohol, the medical examiner reported that this finding was the result of natural body decomposition processes.

Other Risk Factors for HRI and Exertional Heatstroke

Additional risk factors for HRI and heatstroke include dehydration, lack of heat acclimatization, sleep deprivation and fatigue, and rhabdomyolysis [Armstrong et al. 2007]. The following discussion provides background on these issues and addresses whether they may have been a factor in this incident.

Dehydration. Dehydration occurs during prolonged exertion when fluid losses from sweating and rapid breathing are greater than fluid intake. The reduced intravascular volume associated with dehydration results in reduced blood flow to the skin (convection heat loss) and reduced sweating (evaporative heat loss), two of the body's most important cooling mechanisms [Lugo-Amador et al. 2004]. Impaired cooling increases the body's core temperature, which increases the risk of exertional heatstroke. Throughout the FF's deployment and training, debriefing sessions emphasized the risk of heat stress and the importance of drinking water and sports drinks to prevent dehydration. Water access during this incident was not reported as a problem and the FF drank adequate amounts of water during his

deployment. Although the autopsy report listed "probable dehydration due to physical exertion" as a contributing factor, the levels of urea nitrogen and creatine measured in vitreous fluid suggest the FF was not dehydrated [Collins 2011].

Acclimatization. Lack of heat acclimatization is another heatstroke risk factor. With heat acclimatization, physiological changes (sweating at a lower temperature, more sweating, less electrolyte loss, etc.) help the body respond to heat stress. Any exercise program that builds and maintains a high level of aerobic fitness partially adapts the body to heat stress [Nunneley and Reardon 2009]. To fully acclimatize, however, the body needs to experience the actual work conditions in consecutively increasing 1½- to 2-hour increments. Adaptive physiological changes occur within 4 days, but complete acclimatization can take up to 3 weeks [Voltaire et al. 2002]. Once heat stress exposure stops, the body's adaptive mechanisms regress; clinically significant reductions are seen within 4 days [ACGIH 2011]. With 1 to 2 weeks without exposure, re-acclimatization requires 4 to 7 days (Figure 1) [Bass 1963; ACGIH 2011]. Having been in Arizona for only 4 days prior to this incident, it is likely the FF was not fully acclimatized.

Sleep Deprivation. Exhaustion is a physiologic response to work defined as the inability to continue exercise and occurs with heavy exertion in all temperature ranges [Armstrong et al. 2007]. Several variables affect exhaustion in athletes including personal factors like medications, supplements, sleep, and recent illness [Armstrong et al. 2007]. The risk of exertional heat stroke rises substantially when athletes experience multiple stressors such as a sudden increase in physical training, sleep deprivation, and poor nutrition [Armstrong et al. 2007]. There was no indication the FF was sleep deprived.

Fatigue. Heat exhaustion and exercise-related muscle cramps are a result of fatigue, body water and/or electrolyte depletion, and/or central regulatory changes that fail in the face of exhaustion [Armstrong et al. 2007]. The FF was not fatigued prior to taking the pack test.

Rhabdomyolysis. As core body temperature increases, muscle cells begin to break down, releasing myoglobin into the blood stream. This process, known as rhabdomyolysis, has been observed in fire fighters, particularly during physical fitness testing or fire fighter training [CDC 1990; NIOSH 2012; NIOSH 2016]. Rhabdomyolysis can also be a complication of HRI [Huerta-Alardin et al. 2005]. With reduced intravascular volume and reduced kidney blood flow from dehydration, the circulating myoglobin can "clog" the kidneys, resulting in acute tubular necrosis and acute kidney failure [Brown 2004; Sawka et al. 2007]. The histology findings from the FF's autopsy did not indicate acute tubular necrosis. However, rhabdomyolysis cannot be ruled out. Individuals who engage in exertional activities higher than their baseline level of fitness may develop rhabdomyolysis [NIOSH 2016].

Recommendations

Recommendation #1: Provide preplacement and medical evaluations to all fire fighters consistent with NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments, to identify fire fighters at increased risk for CHD.

Discussion: Guidance regarding the content and frequency of these medical evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/International Association of Fire Chiefs (IAFC) *Fire Service Joint Labor Management Wellness/Fitness Initiative* [IAFF, IAFC 2008; NFPA 2013]. Although the Agency is not legally required to follow the NFPA standard or the IAFF/IAFC guideline, doing so will help to ensure the health and safety of candidates and members, and the continuity of medical evaluations.

Recommendation #2: Ensure ice water immersion therapy is rapidly available for training involving heavy physical exertion.

Discussion: In addition to ensuring the availability of a large enough receptacle (e.g., a tank/tub such as a cattle watering trough or a bath tub) and a supply of ice and water, Agency personnel will need training on the symptoms, signs, and initial management of heatstroke.

Recommendation #3: Ensure fire fighters are acclimatized prior to the pack test.

Discussion: If wildland fire fighters have not been working in hot environments, a program of acclimatization should be instituted. The duration of the acclimatization period should be directly related to the length of time without heat exposure. Figure 1 provides guidance on acclimatization schedules. More information is available in "Criteria for a recommended standard: occupational exposure to heat and hot environments" [NIOSH 2016].

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Investigator Information

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

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Appendix A
Autopsy Findings

- Hypertensive heart disease
  - Mild cardiomegaly (heart weighed 400 grams [g]; predicted normal weight is 391 g [ranges between 296 g and 516 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Left ventricular hypertrophy
    - Left ventricle and interventricular septum thickening (1.3 centimeter [cm])
      - Normal at autopsy is 0.76–0.88 cm [Colucci and Braunwald 1997]
      - Normal by echocardiographic measurement is 0.6–1.0 cm [Connolly and Oh 2012]
- No significant atherosclerosis
- Normal cardiac valves
- No evidence of significant dehydration or rhabdomyolysis
    - No specific gravity measurement of the cloudy yellow urine in the bladder
    - No evidence of acute tubular necrosis of the kidney on histology
- No evidence of a pulmonary embolus (blood clot in the lung arteries)

Laboratory Tests
- Positive blood test for alcohol (0.041 % weight to volume [w/v] due to naturally occurring decomposition) (normal is 0) (level of intoxication in Arizona is 0.08%)
- Positive urine test for alcohol (0.025 % w/v) (normal is 0) and for cannabis (25 nanograms per milliliter) (normal is <0.019 micrograms per milliliter) (urine tests do not detect the level of intoxication; only use within 7 days)
- No evidence of dehydration based on the presence of cloudy, yellow urine in the bladder and normal vitreous chemistries [vitreous sodium 138 millimoles per liter (mmol/L) (normal 135-150); potassium 29.4 mmol/L (normal <15); urea nitrogen 10 mg/dL (normal 8-20); creatinine 0.00 mg/dL (normal 0.6-1.3); chloride 114 mmol/dL (normal 105-135)].

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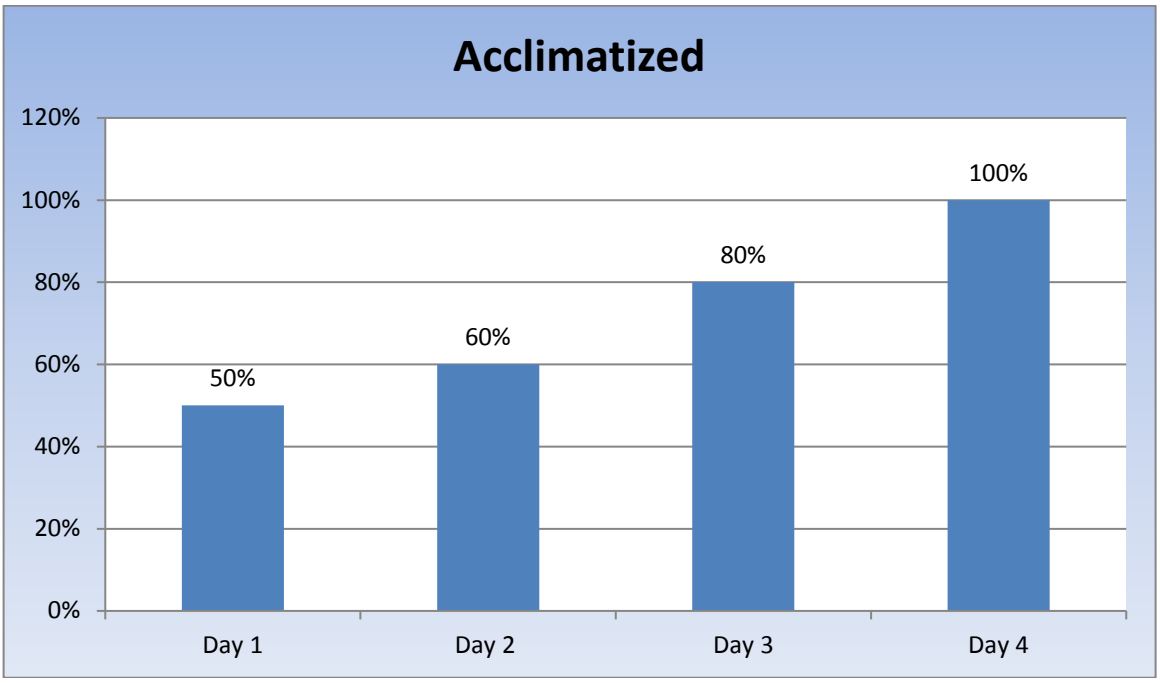
Figure 1: Work Schedule for Heat Acclimatized Employees*
(Based on a 10-hour work shift)



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