# Fire Fighter Physiology

# CHAPTER 4

## NFPA 1403 Standard

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**4.5.8** The instructor-in-charge shall provide for rest and rehabilitation of members operating at the scene, including any necessary medical evaluation and treatment, food and fluid replenishment, and relief from climatic conditions. *(See Annex D.)* [p 64–65, 70–71]

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## Additional NFPA Standards

NFPA 1582 *Standard on Comprehensive Occupational Medical Programs for Fire Departments.*

NFPA 1583 *Standard on Health-Related Fitness Programs for Fire Department Members*

NFPA 1584 *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises*

## Knowledge Objectives

After studying this chapter, you will be able to:

- Describe the cardiovascular and thermal responses to firefighting.
- Describe how firefighting activity and turnout gear affects cardiovascular and thermal strain.
- Describe how fitness levels affect cardiovascular and thermal strain.
- Describe how to prevent injuries, such as heat illness, during firefighting activity and training.
- Describe the warning signs for heat illnesses that may occur in firefighting activity and training.
- Describe how high aerobic fitness is necessary to safely and effectively perform firefighting activity.
- Describe the risk factors for cardiovascular disease.
- Describe the importance of modifiable risk factors for cardiovascular disease, and describe ways to decrease those factors.
- Describe the goals of on-site rehabilitation.

## Skills Objectives

There are no skills objectives for this chapter.

# You Are the Live Fire Training Instructor

You have just been given an assignment to be the instructor-in-charge of a live fire training evolution. Three local fire departments will be present to take part in the exercises. The training will be conducted at a regional training facility and is scheduled for early July. There are many aspects that need to be planned for before this training can be a success. As the training date is approaching, you ask yourself the following questions:

1. What are the primary physiological threats that I must consider in order to ensure the safety of the instructors and students?
2. How will a well-run rehabilitation sector help me address the safety of my students?

## Introduction

Firefighting is an inherently dangerous and physically demanding occupation. Every day, fire fighters are faced with potentially life-threatening challenges, including burn injury, asphyxiation, collapse, and entrapment. Less appreciated, however, are the physiological consequences that threaten fire fighters. The combination of strenuous work, heavy and encapsulating personal protective equipment (PPE), hot and hostile fire conditions, and high adrenaline levels leads to significant levels of cardiovascular and thermal strain during firefighting.

Live fire training is necessary to prepare fire fighters for the dangerous and challenging environment in which they are expected to perform. Live fire training places fire fighters in high heat environments with live fire conditions. These intense training sessions can create high levels of cardiovascular and thermal strain, and thus increase the risk for heat-related injuries and sudden cardiac events. Live fire training instructors, in particular, are often exposed to severe heat conditions for prolonged periods of time. The exposure to such severe conditions creates a challenging and potentially dangerous situation for both instructors and students. It is important that the risks to fire trainees and fire instructors are managed effectively, so that they do not outweigh the benefits. The focus of this chapter is to help you understand the following:

1. How the body responds to firefighting activity
2. The dangers associated with these responses
3. Effective strategies to minimize the risk of heat-related or cardiac-related events

## Cardiovascular and Thermal Strain of Firefighting

As a result of the combination of heavy work, heavy and encapsulating PPE, and hot and hostile environmental conditions, firefighting creates significant physiological strain, affecting nearly every system of the body. The greatest risks to the fire fighter come from the ensuing cardiovascular and thermal strain. The NFPA 1403, *Standard on Live Fire Training Evolutions*, mandates that live fire training evolutions be done in such a way as to minimize the exposure to health and safety hazards for the fire fighters involved. In terms of human physiology, this means recognizing the thermal strains and cardiovascular strains associated with firefighting and pursuing measures to minimize those risks.

Research studies have found that strenuous firefighting activities lead to near maximal heart rates that remain high for extended periods of time during fire suppression activities. As early as the mid-1970s, there were studies reporting the heart rates of on-duty fire fighters. The researchers documented one individual with a heart rate over 188 beats per minute for a 15-minute period compared to the average adult's heart that beats between 60 and 100 times per minute. These findings have been confirmed and extended by recent studies focusing on the physiological responses to firefighting.

Researchers at the University of Illinois have conducted a series of studies to document the effects of firefighting activities on the cardiovascular system. The research studies were conducted in a live fire training structure in moderate temperate conditions (≈ 120°F–150°F [49°C–65°C]). Fire fighters completed three repeated trials (≈ 7 minutes) of simulated firefighting activity lasting a total of 21 minutes with a 10-minute rest between the second and third trial. The study resulted in average heart rates of approximately 190 beats per minute, which is equal to the age-predicted maximal heart rates for these fire fighters Figure 4-1. **Stroke volume**, which is the amount of blood pumped with each beat of the heart, decreased by about one-third by the end of the third trial. This finding is especially troubling because the amount of blood being pumped out of the heart is decreased at the very time it is most needed. During firefighting, blood needs to be delivered to many areas of the body, such as the following:

- The working muscle to support contraction
- The skin to cool the body
- The heart to support increased work associated with elevated heart rate
- Other vital organs including the brain

**Core temperature**, or the temperature of the central part of the body, rapidly increases during firefighting activity. In one study, fire fighters who completed three repeated bouts of firefighting activity, each bout lasting approximately 6 minutes with a 10-minute break between the second and third trial, experienced an average increase in body temperature of 2.5°F (1.7°C). A British study that measured the core temperature of fire instructors reported an average increase in core temperature of 1.8°F (1°C) over the 40 minutes of live fire training evolutions. Mean core temperature increased to 101.3°F (38.5°C), and 8 of the 26 instructors had core temperatures over 102°F (38.8°C) after just 40 minutes of data collection. In a companion study, researchers investigated the ability of live fire training instructors to perform a simulated rescue after 40 minutes of a live fire training evolution. Ten minutes after the live fire training evolution, fire instructors were required to drag a 187 lb (84.8 kg) dummy 98 ft (29.9 m). In six out of seven trials they were able to do so. The authors concluded that *most* of the fire instructors were able to perform a rescue task after live fire training evolutions, but they were approaching their physical limit.

In addition to elevated body temperature, firefighting also causes profuse sweating. The body sweats in an attempt to cool itself through a process called evaporative cooling. Unfortunately for fire fighters, PPE creates a warm, moist, and stagnant air layer next to the skin, which severely limits the evaporation of sweat. Without the evaporation of the sweat, the body becomes unable to utilize evaporative cooling as a method for temperature control. Profuse sweating can also decrease plasma volume, placing additional strain on the cardiovascular system and further impairing thermoregulation. Researchers found a 15 percent reduction in plasma volume following approximately 18 minutes of strenuous simulated firefighting activity. Sweat loss of 2.8 (1.3 kg) pounds per hour have been reported during exercise in a hot environment while wearing PPE. Sweat loss is a major concern during live fire training because individuals may be engaged in training over a relatively long time period. Furthermore, training on consecutive days may present an additional challenge if individuals do not fully rehydrate in between training days.

## Live Fire Tips

Firefighting training causes significant cardiovascular and thermal disruption, including the following:

- Increased core temperature
- Profuse sweat loss
- Near maximal heart rate
- Decreased stroke volume
- Decreased plasma volume

These physiological changes can lead to life-threatening pathological conditions including heatstroke and sudden cardiac events in extreme cases.

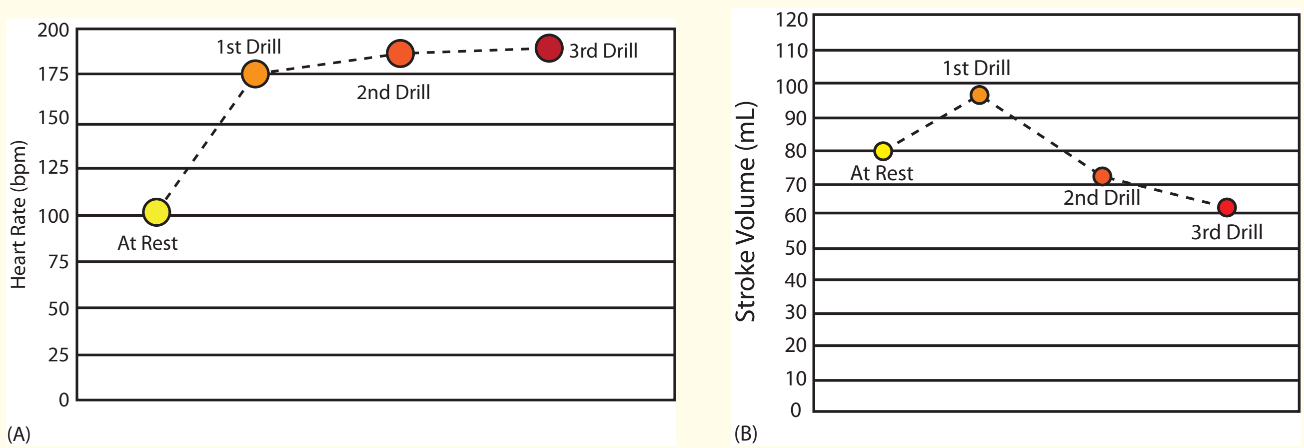


Figure 4-1 **A.** Heart rate and **B.** Stroke volume responses to 3 trials of firefighting drills. Each drill consisted of ≈ 7 minutes of firefighting activity.

# Factors Affecting Cardiovascular and Thermal Strain

The magnitude of the thermal and cardiovascular strain experienced by a fire fighter depends on several interrelated environmental and personal factors Figure 4-2.

## Environmental Conditions

Environmental conditions are a major contributing factor to the physiologic stresses of firefighting. In most cases, this means that the heat of the fire contributes to the total heat stress of the individual. Performing any task in a hot, oppressive environment creates greater physiological strain than performing the same task in moderate conditions. The environment in which fire fighters and live fire training instructors conduct live fire training varies greatly from a moderate level of heat to conditions so severe that they can only be tolerated for a brief period of time before damage to PPE can occur and physical injury can result.

An instructor must consider the potential for burn- and heat-related injuries when working in different conditions. Heat exposure can be in the form of the ambient environment or direct exposure to flames or another heat source. Heat exposure poses different challenges to the human body depending on the absolute temperature, or heat flux, and the duration of exposure. High ambient conditions combined with direct radiant heating will increase the effects on the human body. The effects of heat and the length of time the human body can sustain such conditions will depend on the intensity of the heat source and the duration of the exposure.

Provided below is a chart that identifies routine, hazardous, extreme, and critical exposures that fire fighters may encounter Figure 4-3. Individuals should not be exposed to critical conditions in training settings. It is important to keep in mind that even exposure to "routine" conditions presents a considerable challenge to the human cardiovascular and thermoregulatory systems.

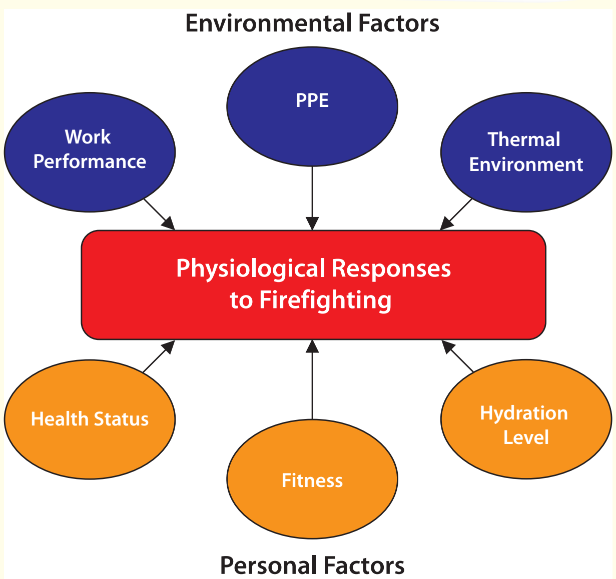


Figure 4-2 Factors affecting physiological responses to firefighting.

## Work Performed

On the fireground and in training scenarios, there are a number of different tasks performed, including throwing ladders, climbing stairs with heavy loads, performing a search, advancing a line, forcing open a door, and overhauling a room. The individual tasks, and the intensity at which they are performed, have a strong influence on physiological responses to firefighting. Clearly, the work being performed has a major influence on the physiological response of the body—the more strenuous the work and the longer the duration, the greater the cardiovascular response. Physical work creates metabolic heat, which leads to an increase in body temperature, and thus adds additional cardiovascular strain.

## Personal Protective Equipment

PPE is necessary to protect fire fighters from burn and inhalation injuries. Because of its weight and restrictive properties, PPE adds to a fire fighter's work. PPE also interferes with heat loss, because of encapsulation. Thus, PPE adds to the cardiovascular and thermal strain associated with firefighting. In one laboratory study, fire fighters were asked to walk in full PPE with a self-contained breathing apparatus (SCBA). The fire fighters reached heart rates around 178 beats per minute, which is, on average, 55 beats per minute higher than walking in a station uniform alone.

Wearing PPE is absolutely essential to safety in training evolutions, however, it does add to the physiological stresses that the live fire training fighter encounters. Thus, a live fire training instructor should be aware of the amount of time that trainees are in full gear. During debriefing periods, breaks, and rehabilitation, gear should be removed to allow for recovery.

To combat the dangers of heat illness, it is important that instructors and students remove their PPE and cool down. The

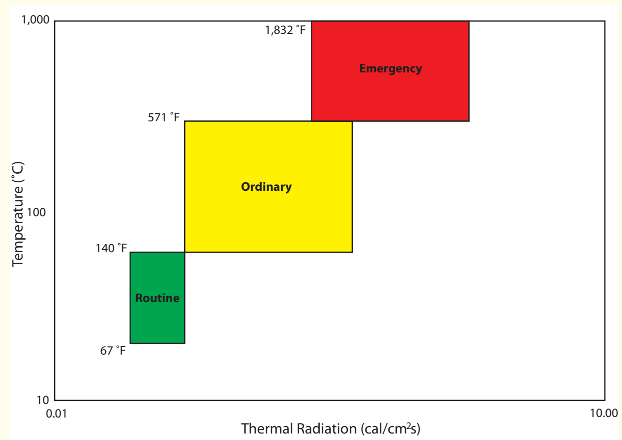


Figure 4-3 Levels of exposure encountered during firefighting.

**Safety Tips**

PPE is essential to protect fire instructors and students from burn injuries and smoke inhalation and should be worn in compliance with manufacturer's recommendations and local policies during live fire training. However, the live fire training instructor must also understand how the weight and insulative properties of PPE add to heat stress and cardiovascular strain. PPE should be doffed, when appropriate, to allow body temperature to decrease.

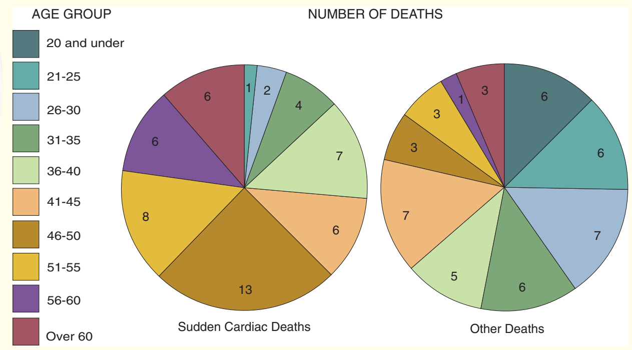


**Figure 4-4** Training fatalities by age and cause of death (1996–2005). Based on data from NFPA.

air outside is much cooler than the air inside of a fire fighter's gear, which will cause sweat to evaporate as gear is removed, giving the fire fighter a feeling of being cool. However, body temperature does not decrease as quickly as the mind perceives it to. In fact, body temperature often continues to rise, even after firefighting activity has ended. Therefore, to decrease body temperature, it is necessary to doff the bunker coat and pants.

## Individual Characteristics

A fire fighter's age, gender, and body size all affect the physiological response to firefighting activity. In general, the risk of heart attack while performing firefighting work increases as the age of the fire fighter increases. The number of fatalities due to sudden cardiac events versus other causes during training over a 10-year period is shown in **Figure 4-4**. Note that as age increases, so does the percentage of fatalities due to sudden cardiac events. What may be surprising is the number of cardiac events that occur in young fire fighters. Instructors must not become complacent when working with young fire fighters.

Excess body fat creates additional cardiovascular strain on a fire fighter by adding to the metabolic work that must be done to move his or her body mass. Excess body fat also increases the thermal strain by providing insulation, impeding the range of motion and mobility, and interfering with heat dissipation.

## Medical Conditions

Firefighting activities can be extremely strenuous. Fire fighters should be in good health to be able to operate safely on the fireground or in a training situation, because of the combination of heavy work, severe heat, and mental stress. A live fire training instructor who is not medically cleared for firefighting presents a risk not only to himself, but also to the students under his or her command. A fire fighter with a preexisting cardiovascular disease is more susceptible to cardiac events on the fireground because of the additional cardiovascular strain associated with firefighting. In fact, a retrospective analysis of sudden cardiac events over a 10-year period found that 75 percent of fire fighters who suffered fatal cardiac events had preexisting cardiovascular conditions. High blood pressure, high cholesterol, and obesity are factors that greatly increase the risk of cardiovascular mortality and should be taken very seriously. Diabetes and pre-diabetes (impaired glucose tolerance) are especially dangerous because they are associated with several cardiovascular risk factors.

NFPA 1582, *Standard on Comprehensive Occupational Medical Programs for Fire Departments*, identifies the 13 essential tasks of firefighting and provides guidelines for the medical clearance of fire fighters. In order to ensure that fire instructors can safely engage in live fire training and meet the responsibilities they have to their students, they should have a medical examination that meets the NFPA 1582 standard.

## Fitness Level

Firefighting is physically demanding work and a high level of fitness is necessary to safely and successfully perform the job duties. A fit fire fighter can perform the same amount of work with less cardiovascular and thermal strain than a less fit fire fighter. A fit fire fighter also has a greater energy reserve needed to perform more work. Fire fighters need to possess a high degree of muscular fitness (muscle strength and endurance) and cardiovascular fitness (aerobic fitness). Cardiovascular fitness is especially important because it does the following:

- Increases the efficiency of the heart
- Improves work capacity
- Increases plasma volume
- Improves thermal tolerance
- Decreases tendency of blood to clot
- Enhances the ability of blood vessels to dilate to allow more blood to be supplied to muscles

The components of a health-related fitness program are outlined in NFPA 1583, *Standard on Health-Related Fitness Programs for Fire Department Members*. As an instructor, you have an obligation to pay careful attention to your own fitness level because of the following:

- Your fitness level directly affects your risk of heat-related illness or sudden cardiac events during training.
- Your fitness level affects your ability to perform strenuous firefighting activity, including the possibility of needing to rescue a participant.
- You are a role model for your students and your approach to fitness will affect your students' attitude toward fitness and their respect for you.

## Hydration Status

Firefighting leads to a large amount of sweat loss due to the heavy work, hot conditions, and the impermeable nature of the PPE. During strenuous work in hot conditions, or in protective clothing, humans can lose more than two quarts of sweat per hour. This sweat loss contributes to a decrease in plasma volume, adds additional strain on the cardiovascular system, and decreases the ability to work in the heat, also known as **thermal tolerance**. Instructors need to pay careful attention to their own hydration status as well as ensuring their students consume adequate fluid during training drills.

Live fire training instructors need to be well hydrated before they begin training drills and need to be vigilant about consuming water or sports drinks throughout the training evolutions. Likewise, instructors must be diligent in providing opportunities for students to properly rehydrate during the training drills. Thirst is an inadequate mechanism of ensuring that adequate fluids are consumed to avoid dehydration. Therefore, the instructor should have structured breaks during which rehydration is emphasized.

The human body is comprised of approximately 60 percent water, and proper hydration is necessary for biological function. Water is constantly lost from the body by urinating, sweating, and breathing, so it is critical to replenish the supply. A sedentary person requires approximately 30 ml (1 oz.) of water per kilogram (1 kg = 2.2 lbs) of body weight per day. Thus, a man who weights around 154 lbs (70 kg) needs to consume about 2100 mL (2 qts) of water to remain hydrated when he is not engaged in strenuous work or sweating profusely. Exercise or work under hot conditions, such as those routinely encountered during firefighting, can dramatically increase the need for fluid. Humans routinely lose between 1–2 liters (1 L = 1.06 quarts) of sweat per hour when working in hot and humid environments. Given that training often occurs over a period of several hours, this high rate at which sweat is lost can lead to severe dehydration. Fire fighters should be mindful to consume adequate fluids to replace what is lost during normal fluid turnover plus what is lost with sweating. Furthermore, fluid ingestion should be done primarily with water or a low-calorie sports beverage. Caffeinated beverages such as coffee, tea, and soda can act as a diuretic and increase water loss, exacerbating rather than helping dehydration. An additional concern is that many drinks, including soda and sweetened tea, include a lot of sugar, which is often associated with excess body weight, another factor that increases heat stress.

Given the detrimental effects of dehydration, and evidence that many fire fighters are dehydrated even before beginning work, it is a good idea to monitor your hydration status. The easiest way to do this is the use of a simple urine chart **Figure 4-5**. These charts can be placed in rest rooms to serve as a reminder to instructors and students that urine should be a light color and should not have a strong odor. Urine color is affected by many factors, including medication and diet, so it is wise to have individuals follow a hydration program that ensures that they are well hydrated. From there, one should be able to determine the proper color of their urine. Students and instructors should be reminded regularly to consume fluid that ensures light urine or urine that is consistent with their urine color in a well hydrated state.

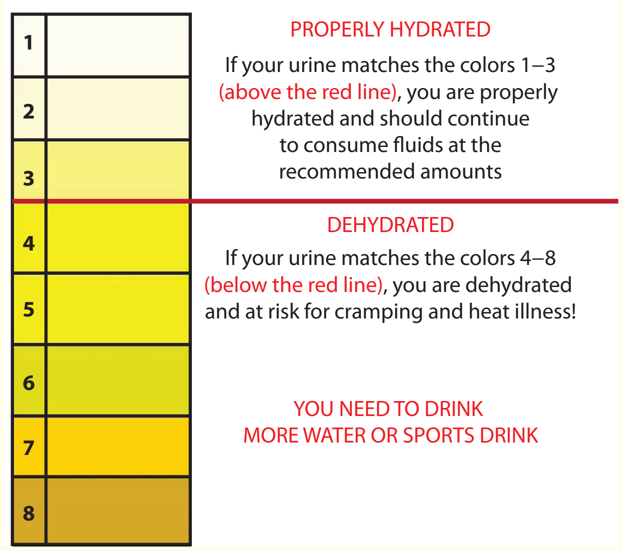


**Figure 4-5** Urine color and hydration.

### Safety Tips

Dehydration is dangerous, it increases the risk of heat illness and sudden cardiac events, and unfortunately it is very common among students undergoing live fire training. Several major reports in the fire service have documented that students commonly show up for training dehydrated. It is important that efforts be made to get students and instructors to begin training in a well-hydrated state. To prevent excessive dehydration, instructors must provide frequent water breaks and should have policies that mandate fluid ingestion, including water and sports drinks. Instructors and participants should be encouraged to drink more fluids the day before attending live fire training to prehydrate.

## Heat Emergencies

Heat illnesses can be fatal, and there are far too many instances of fire fighters suffering fatal heatstroke during training. Instructors have an obligation to be alert to the dangers of heat illness and to help decrease the number of fatal heat illnesses that occur in training. The United States Fire Administrations report, *Emergency Incident Rehabilitation*, released in 2008, documents seven case studies in which fire fighters have died due to heat illness following work or training. These tragic case studies should be read by every fire instructor because of the lessons that can be learned from them, the first of which is that fatal heatstroke can occur during training. Another important and related lesson is that heatstroke can affect young and old fire fighters alike. In fact, young recruits are especially vulnerable because of their extreme motivation to succeed in the training environment. Under these conditions, many young fire fighters push themselves far beyond what is physiologically safe.

Working in protective clothing with high ambient temperatures presents a serious challenge to the thermoregulatory and cardiovascular systems. If the cardiovascular system cannot meet the simultaneous demands of supplying adequate blood to the muscles and maintaining thermal balance, heat illness may ensue. Heat illness covers a spectrum of disorders from heat rash to life-threatening heatstroke. Heat-related illnesses occur because the body is unable to maintain thermal balance.

## Thermal Balance

Normally, the body regulates its internal body temperature within a narrow range, despite wide variations in environmental temperatures. The process by which the body regulates body temperature is called **thermoregulation**. The human body typically regulates its temperature around 98.6°F (37°C). It is important to maintain a temperature within approximately 1.5°F (0.7°C) of this temperature because changes in body temperature dramatically affect biological function. Greater temperature changes can alter chemical reactions and, ultimately, directly damage body tissue.

Body temperature results from a balance between heat gain and heat loss. Heat can be gained from the environment, when the ambient temperature is higher than the body temperature, and from metabolic heat produced by the body as a result of muscular work. Heat can be exchanged from the body through four processes: radiation, conduction, convection, and evaporation. The extent of heat gain or loss through these processes depends on environmental conditions such as ambient temperature, relative humidity, and wind speed.

The effectiveness of heat exchange between an individual and the environment is affected by five factors:

1. Thermal gradient
2. Relative humidity
3. Air movement
4. Degree of direct sunlight
5. Clothing worn

The greater the difference between two temperatures, known as the **thermal gradient**, the greater the heat loss is from the warmer of the two. Typically, the body is warmer than the environment, so heat moves down its thermal gradient to the environment. More heat is lost in cooler environments because the thermal gradient is greater. In firefighting situations, heat may be gained by the body.

The body's use of evaporative cooling techniques are decreased in high humidity conditions because the air already contains an abundance of water vapor. Evaporative cooling is largely determined by the relative humidity; on humid days evaporative cooling is limited. Although a fire fighter may sweat profusely when humidity is high, the body doesn't properly cool down because the sweat does not evaporate as effectively.

Air movement increases convective heat loss from the skin to the environment. Thus, on windy days more heat is lost from the body. Conversely, when a fire fighter's skin is covered by heavy PPE, heat loss is minimized.

Direct sunlight can add considerably to the radiant heat load of an individual, just as shade or cloud cover can often provide significant relief from heat. Measures should be taken to avoid having students spend prolonged periods of time in PPE in direct sunlight on hot days, as it can cause dangerous increases in body temperature.

When the body is in thermal balance, the amount of heat lost equals the amount of heat produced, and body temperature remains constant. However, when heat produced (and absorbed) exceeds heat loss, an increase in body temperature occurs. This increase in body temperature places considerable strain on the cardiovascular system, hastens fatigue, promotes sweating and loss of plasma volume, and may lead to serious heat illnesses.

## Heat Illness

Heat illness includes a spectrum of disorders, resulting specifically from the combined stresses of exertion and high heat situations. Heat illness affects many systems of the body and can cause elevated core body temperature and impaired thermoregulation. It varies greatly in severity from heat rash, sunburn, and heat cramps, to heat exhaustion and heatstroke. One of the greatest challenges in dealing with heat illnesses is distinguishing among disorders because they frequently overlap and can evolve into different forms over time. A summary of the causes, signs, symptoms, and treatments for heat illnesses is provided in Table 4-1. This section describes the most common and serious heat illnesses encountered during live fire training, namely heat cramps, heat exhaustion, and heatstroke. Symptoms of heat illness may be nonspecific, particularly in the early stages. As heat illnesses progress, so does the severity of signs and symptoms.

### Heat Cramps

Heat cramps are an acute disorder consisting of brief, recurrent, and excruciating pain in the voluntary muscles of the legs, arms, or abdomen. Typically, the muscles have recently been engaged in intense physical work and are fatigued. Heat cramps may result from a fluid/electrolyte imbalance. Individuals who sweat profusely or who lose large quantities of sodium (salt) may be more susceptible than others.

Table 4-1 **Heat Illness Classifications**

| Classification | Cause | Signs and Symptoms | Treatment | Prevention |
|---|---|---|---|---|
| **Heat Rash** (also called prickly heat or miliaria) | Hot, humid environment; clogged sweat glands | Red, bumpy rash with severe itching | Change into dry clothes and avoid hot environments. Rinse skin with cool water. | Wash regularly to keep skin clean and dry. |
| **Sunburn** | Too much exposure to the sun | Red, painful, or blistering and peeling skin | If the skin blisters, seek medical aid. Use skin lotions (avoid topical anesthetics) and work in the shade. | Work in the shade; cover skin with clothing; apply skin lotions with a skin protection factor of at least 15. Fair people have greater risk. |
| **Heat Cramps** | Heavy sweating depletes the body of salt, which cannot be replaced just by drinking water. | Painful cramps in arms, legs, or stomach that occur suddenly at work or following work. Heat cramps are serious because they can be a warning sign of other more dangerous heat-induced illnesses. | Move to a cool area; loosen clothing and drink commercial fluid replacements (sports drinks). If the cramps are sever or don't go away, seek medical aid. | Reduce activity level and/or heat exposure. Drink fluids regularly. Workers should check each other to help spot the symptoms that often precede heatstroke. |
| **Heat Exhaustion** | Fluid loss, inadequate salt, and the cooling system begins to break down | Heavy sweating; elevated body temperature; weak pulse; normal or low blood pressure; person is tired and weak or faint, has nausea and vomiting, is very thirsty, or is panting or breathing rapidly; vision can be blurred. | **GET MEDICAL AID.** This condition can lead to heatstroke, which can kill. Remove gear, move the person to a cool shaded area; loosen or remove excess clothing; provide sports drink. Use active cooling (forearm immersion, misting fans, or cold towels) to lower core body temperature. | Reduce activity level and/or heat exposure. Drink fluids (water and sports drink) regularly to compensate for sweat loss. Monitor participants frequently to assess symptoms. |
| **Heatstroke** | Elevation of body temperature due to a breakdown of thermoregulatory mechanisms. Caused by depletion of salt and water reserves. Heatstroke can develop suddenly or can follow from heat exhaustion. | Body temperature is very high and any of the following; the person is weak, confused, upset, or acting strangely; has hot, dry, red skin; a fast pulse; headache or dizziness. In later stages, a person can pass out and have convulsions. | **IMMEDIATELEY TRANSPORT TO A MEDICAL FACILITY.** This is a life-threatening emergency. If transport is delayed, immediately immerse body in cold water. | Reduce activity level and/or heat exposure. Drink fluids (water and sports drink) regularly to compensate for sweat loss. Monitor participants frequently to assess symptoms. |

Note: Modified from NFPA 1584.

## Heat Exhaustion

Heat exhaustion is characterized by elevated body temperature and decreased pumping capacity of the heart (cardiac output). Heat exhaustion is caused by severe fluid loss and the inability of the cardiovascular system to properly compensate for the demands of blood flow to both muscles and the skin. A fire fighter with heat exhaustion will likely have some combination of the following signs and symptoms:

- Rapid and weak pulse
- Fatigue and weakness
- Profuse sweating
- Confusion or disorientation
- Dizziness or fainting

If untreated, heat exhaustion can lead to moderate to severe multiple-organ damage. If heat exhaustion is not aggressively treated, it can lead to heatstroke. A fire fighter who is suspected of suffering from heat exhaustion should discontinue activity and doff his or her gear. The fire fighter should receive a medical evaluation and be cooled and hydrated. Depending on the medical evaluation and the severity of the symptoms, the fire fighter may need to be transported to the hospital for further medical care.

## Heatstroke

Heatstroke is a life-threatening emergency that requires immediate medical care and rapid cooling. Heatstroke involves multiple-organ damage and is often characterized by central nervous system dysfunction, including disorientation, seizure, and cardiovascular collapse. Signs that may indicate heatstroke include the following:

- Elevated skin and core temperature
- Rapid heart rate
- Vomiting
- Diarrhea
- Hallucinations
- Seizures
- Coma

Heatstroke involves a complete failure of the thermoregulatory mechanisms. If heatstroke is suspected, medical treatment must be summoned immediately and the individual must be cooled as quickly as possible using water, ice, or a fan.

## Risk Factors for Heat Illness

A risk factor is something that increases a person's chances of developing an infection or disease. Many factors affect a fire fighter's risk for heat illness. Many of these factors, namely fitness level, excess body fat, hydration level, and medical conditions, were discussed earlier and are also summarized in Table 4-2. However, given their importance in increasing the risk of serious heat illness, they warrant review. A fire fighter who is unfit, overweight, or has preexisting medical conditions is at a much greater risk for suffering from heat-related illnesses. Furthermore, there are a large number of medical conditions, both serious and seemingly minor, that can affect the body's fluid balance and thermoregulatory capacity. Two factors that are often overlooked are gastrointestinal problems and skin irritations. Gastrointestinal problems include anything that causes loose bowel movements and loss of fluids and electrolytes. Skin irritations can interfere with the skin's role in sweat loss or heat dissipation. There are dozens of prescription and over-the-counter medications, ergogenic aids, supplements, and illegal drugs that can increase the risk of dehydration or heat-related injuries. Commonly used medications that can increase the risk of heat illness include, antihistamines, antidepressants, ephedrine, diuretics, and beta-blockers.

Individuals who have previously suffered heat illness appear to be more likely to suffer subsequent bouts. It is unclear if the same factors that originally caused the heat illness are responsible for the subsequent bouts, or if a damaged thermoregulatory system caused by heat illness makes repeat bouts more likely. Regardless of the mechanisms, it is prudent to ask students if they have suffered from heat illness in the past. If they have, additional caution is warranted.

Surprisingly, data from the military shows convincingly that one of the greatest predictors of heat illness is the weather conditions on the day *prior* to training. While a live fire training instructor will likely be aware that he or she must consider environmental conditions on the day of training, it is also imperative to consider the previous day's conditions and activities. This information is particularly relevant to students undergoing several subsequent days of training, but is also applicable to students who are training after a duty day or after strenuous work on an off-duty day. Alcohol use, both chronic and recent, increases the risk for heat illness. Efforts should be made to ensure that students attending special training sessions limit alcohol consumption on the day preceding training.

**Table 4-2 Risk Factors for Heat Illness**

| Risk Factor | Description |
|---|---|
| Poor physical fitness | Poor fitness decreases thermal tolerance and increases risk for heat illness. |
| Excessive body weight | Excess body fat decreases heat dissipation, increases the amount of metabolic work that must be done to move the body, and increases the risk for heat illness. |
| Dehydration and salt depletion | Dehydration increases the risk of heat illness. |
| Chronic disease | Disease such as diabetes mellitus, cardiovascular disease, and congestive heart failure increase risk for heat illness. |
| Minor illness | Fire fighters who were already suffering from a minor illness, inflammation, or fever have an increased chance of heat injury due to a previously compromised autoimmune system; subjects with some form of gastroenteritis are particularly at risk because they may already be dehydrated and have salt and mineral imbalances within their bodies. |
| Skin problems | Skin irritations such as rashes, prickly heat, sunburn, burns, psoriasis, eczema, and poison ivy increases susceptibility to heat illness. |
| Medications, both prescription and nonprescription | Many medications affect the body's hydration level, ability to process fluids, and other bodily functions relative to dealing with the heat. Diuretics reduce fluids in the body. |
| Age | Individuals over 40 years of age, even those in relatively good physical condition, have an increased risk for heat illness. However, young people are susceptible too, especially when highly motivated. |
| High level of motivation | People who are highly motivated and committed to performing given tasks at all costs may overlook the signs of heat illness and increase their chance of overextending themselves. Fire fighters engaged in highly charged emergency scene operations or high-stakes training are clearly at increased risk of heat illness. |
| Prior heat exposure | The body needs more time to fully recover from exposure to heat and stress multiple times per day. Repeated exposure to heat day after day can also increase the risk of heat emergencies. |
| Prior heat injury | A heat illness may result in expedited heat illness and increases the likelihood of subsequent heat illness. |
| Recent alcohol use | Recent alcohol use will increase the likelihood of dehydration and heat illness and can impair the person's judgment. |
| Genetics | People who have genetic mutations, such as cystic fibrosis and malignant hyperthermia, have increased risk of heat illness. |
| Lack of heat acclimatization | Unaccustomed activity in the heat increases risk of heat illness. |

Repeated exposure to work in the heat leads to acclimatization. Lack of acclimatization, or unaccustomed work in the heat, increases the risk for heat illnesses. A live fire training instructor should be mindful of the extent to which students are used to working in the heat. Extra caution should be taken when training is undertaken with individuals who have not been working in the heat. This often occurs during the first hot days of summer.

## Prevention of Heat Illness

Although instructors must be able to recognize and respond to heat illness, it is far preferable to prevent heat-related illness by using sound judgment and observing basic recommendations.

NFPA 1403 states that the training session shall be curtailed, postponed, or canceled, as necessary, to reduce the risk of injury or illness caused by extreme weather conditions. Thus, one of the primary responsibilities of the instructor-in-charge is to determine if training should continue or be modified in some way to prevent undue risk of heat-related injuries. The annex to NFPA 1403 provides useful information to be considered when making these determinations. A HUMIDEX chart, used by the Canadian government, is very useful because it combines air temperature and humidity into one number that reflects the perceived temperature **Table 4-3**. This chart relies on measurements that are readily available (temperature and humidity) and provides guidelines to the level of caution associated with various perceived temperatures. This chart is very similar to the Heat Stress Index used by the US government. An example of Heat Stress Preventive Guidelines based on the HUMIDEX is provided in **Figure 4-6**.

It is critically important that fire instructors be mindful of the need for periodic breaks. Fire fighters need to have time to cool down, rehydrate, and allow their bodies to recover. In some instances students are asked to assist with evolutions in some way when they rotate out of specific training tasks. This may limit the fire fighter's ability to adequately recover.

It is absolutely essential that aggressive rehydration programs be implemented during training drills. Clean, cold water and sports drinks should be readily available and drinking should be encouraged.

### Live Fire Tips

In order to prevent heat illness, fire instructors should do the following:

- Be alert to conditions that increase an individual's risk for heat illness.
- Consider curtailing, postponing, or canceling training when severe weather increases the risk of heat-related injuries.
- Provide frequent breaks for those involved.
- Encourage rehydration among all participants.
- Establish effective incident-scene rehabilitation.
- Monitor students for signs and symptoms of heat illness.

**Table 4-3 HUMIDEX Chart**

Percent Relative Humidity

| Air Temp °C | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 | 47 | 49 | 51 | 54 | 56 | | | | | | | | | | | | | |
| 42 | 46 | 48 | 50 | 52 | 54 | 56 | | | | | | | | | | | | |
| 41 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | | | | | | | | | | | |
| 40 | 43 | 45 | 47 | 49 | 51 | 54 | 56 | 58 | | | | | | | | | | |
| 39 | 41 | 43 | 45 | 47 | 49 | 51 | 52 | 54 | 56 | 58 | 59 | | | | | | | |
| 38 | 40 | 42 | 43 | 45 | 47 | 49 | 50 | 52 | 54 | 56 | 57 | 59 | | | | | | |
| 37 | 38 | 40 | 42 | 43 | 45 | 47 | 49 | 50 | 52 | 54 | 55 | 57 | 58 | | | | | |
| 36 | 37 | 38 | 40 | 42 | 43 | 45 | 47 | 48 | 50 | 51 | 53 | 55 | 56 | 58 | 59 | | | |
| 35 | 35 | 37 | 39 | 40 | 42 | 43 | 45 | 46 | 48 | 49 | 51 | 53 | 54 | 56 | 57 | 58 | | |
| 34 | 34 | 35 | 37 | 39 | 40 | 42 | 43 | 45 | 46 | 47 | 49 | 50 | 52 | 53 | 55 | 56 | 58 | 54+ Extreme Danger |
| 33 | 33 | 34 | 36 | 37 | 38 | 40 | 41 | 43 | 44 | 46 | 47 | 48 | 50 | 51 | 52 | 54 | 55 | |
| 32 | | 33 | 34 | 35 | 37 | 38 | 40 | 41 | 42 | 44 | 45 | 46 | 48 | 49 | 50 | 51 | 53 | 46–53 Danger |
| 31 | | 31 | 33 | 34 | 35 | 37 | 38 | 39 | 40 | 42 | 43 | 44 | 46 | 47 | 48 | 49 | 50 | |
| 30 | | 30 | 31 | 32 | 34 | 35 | 36 | 37 | 39 | 40 | 41 | 42 | 43 | 45 | 46 | 47 | 48 | |
| 29 | | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 46 | |
| 28 | | | 28 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 44 | 40–45 Exreme Caution |
| 27 | | | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | |
| 26 | | | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 36 | 37 | 38 | 39 | 30–39 Caution |
| 25 | | | | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 35 | 36 | 37 | |
| 24 | | | | 24 | 25 | 26 | 27 | 28 | 28 | 29 | 30 | 31 | 32 | 33 | 33 | 34 | 35 | |
| 23 | | | | 23 | 24 | 24 | 25 | 26 | 27 | 28 | 28 | 29 | 30 | 31 | 31 | 32 | 33 | |
| 22 | | | | 22 | 22 | 23 | 24 | 25 | 25 | 26 | 27 | 27 | 28 | 29 | 29 | 30 | 31 | |
| 21 | | | | | 21 | 22 | 22 | 23 | 24 | 24 | 25 | 26 | 27 | 27 | 28 | 28 | 29 | |
| | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | |

Percent Relative Humidity

NOTE: The supervisor in charge of the facility or workplace is responsible for implementing these heat stress prevention guidelines. He or she shall determine the level of PPE required.

**ALERT LEVEL 1 HUMIDEX 30–39**

**Caution:** Fatigue and faintness are possible with physical activity or prolonged exposure. The most likely at risk this level are those performing heavy work for extended periods of time.

(1) Encourage all staff to increase water intake, be observant of signs and symptoms of heat stress (both in themselves and co-workers), and implement precautionary measures to prevent heat-related disorders.
(2) Addtional rest breaks should be introduced to reduce heavy exertion and allow for cooling.

**ALERT LEVEL 2 HUMIDEX 40–45**

**Extreme Caution:** Heat cramps, heat exhaustion, or sunstroke are possible with physical activity or prolonged exposure. An increased number of workers are at risk at this level, including those performing moderate physical exertions.

(1) Postpone optional activities, or reschedule them to cooler times of the day when possible.
(2) Introduce additional rest breaks for workers performing moderate work.
(3) Further reduce heavy work.
(4) Consider cessation of nonessential operations involving heavy physical activity.
(5) Minimize using bunker suits whenever possible.

**Note: All training activities are considered nonessential except recruit training. The following safety precautions shall be implemented when conducting training within this Humidex range.**

(1) Limit recruit live fire burns to occur between 0700–1200 hours only.
(2) Provide increased rest breaks for all work loads.
(3) Limit heavy work to less than 15 minutes per hour.
(4) Initiate rehabilitation at the beginning of the incident.
(5) Use active cooling where possible (forearm immersion, misting fan, and/or air conditioning).

**ALERT LEVEL 3 HUMIDEX 46–53**

**Danger:** Heat cramps, heat exhaustion, or sunstroke are likely. Heat stroke is possible with physical activity or prolonged exposure. Even those performing light work might require addtional rest breaks.

(1) Significantly reduce both heavy moderate work.
(2) Minimize using bunker suits whenever possible.
(3) Consider cesstion of nonessential operations involving moderate physical activity in this environment.
(4) Cease all nonessential operations involving heavy physical activity.

**Note: All outdoor training activities are considered nonessential and shall be rescheduled or cancelled.**

**ALERT LEVEL 4 HUMIDEX 54 or greater—EMERGENCY HEAT ALERT**

**Extreme Danger:** Heat stroke or sunstroke imminent, danger of DEATH. This is an extremely dangerous humid level, where all individuals are at risk of heat-related disorders, regardless of the workload.

(1) Minimize using bunker suits whenever possible.
(2) Discontinue all nonessential services performed in this environment.
(3) For essential operations, do the following:
  (a) Provide increased rest breaks for all workloads.
  (b) Limit heavy work to less than 15 minutes per hour.
  (c) Initiate rehabilitation at the beginning of the incident.
  (d) Use active cooling (forearm immersion, misting fan, and air conditioning).
  (e) Call for additional crews to facilitate rehabilitation.

**Note: All outdoor training shall be rescheduled or cancelled.**

**Figure 4-6** Heat stress prevention guidelines.

Incident scene rehabilitation is a mechanism to ensure that fire fighters have scheduled rest breaks that provide an opportunity to cool down, rehydrate, and recover. Incident scene rehabilitation should also provide for medical monitoring of fire fighters. The goals of incident scene rehabilitation and some recommendations for effectiveness are provided later in this chapter.

# Incident Report

## Poinciana, Florida - 2002

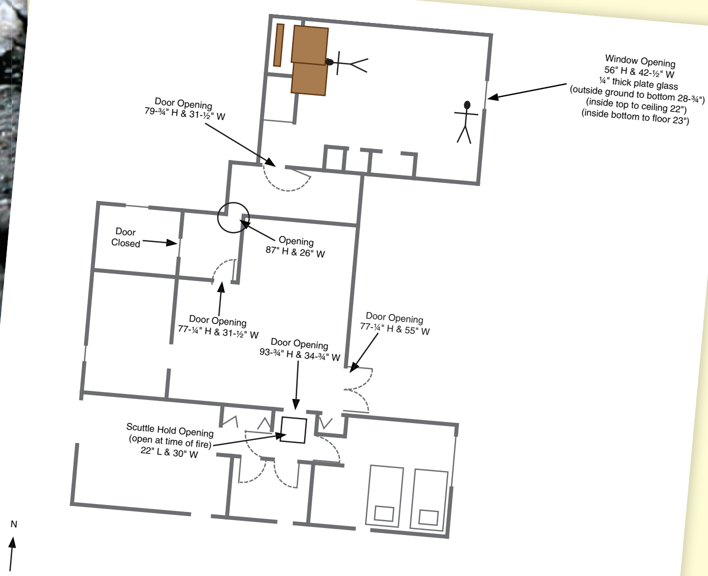


**Figure A** Poinciana floor plan.

**Figure B** Two consecutive offset turns and this narrow hallway made it difficult for fire fighters to maneuver.

Just 10 months after the incident in Lairdsville, and less than three weeks after the sentencing of the Lairdsville chief officer, a live fire training session trapped two fire fighters in Poinciana, Florida, near Kissimmee.

The 1600 $ft^2$ (148.6 $m^2$) cement block house had three bedrooms, one of which was converted from a one-car garage with the large door removed, the wall blocked up, and a window installed **(Figure A)**. The room had block walls, one door, and a fixed ¼" (6.4-mm) thick, commercial-grade glass window. The exit from the room was through two consecutive offset turns, through a 26" (66 cm) opening, then through two small rooms, and out another door into the dining room **(Figure B)**. A breezeway between the old garage and the main house had also been enclosed. Unlike many acquired structures, this house was in good condition and was part of an entire neighborhood being razed for a new campus. Several area fire departments were involved in a series of training events, and the structures available included other houses, as well as a motel.

All of the instructors were experienced in the fire service and had previously worked together on training fires. Safety crews were not briefed at the beginning of this exercise because of their past involvement. The training officer walked all of the participants through the structure and explained the safety aspects and goals of the training evolution, which were to conduct a search and rescue with an actual fire burning and find a mannequin in bunker gear hidden somewhere in the house and remove it. The first search team consisted of an experienced lieutenant and a trained recruit (state certified Fire Fighter II), who were to search without a hose line. Two suppression teams with 1¾" (44 mm) hose lines were in position in the house with four interior safety officers broken into two teams.

The fire was started in the converted bedroom near the only doorway to the fire room **(Figure C)**. Two piles, practically vertical with pallets, wood scraps, and hay, were almost adjacent to each other, one inside and one outside the open closet. After the fire started, and with the instructor-in-charge's agreement, a foam mattress from one of the other bedrooms was added to the pile.

The search and rescue (SAR) team entered the structure at the front (east) door with a suppression team following. The suppression team stopped in the small room located between the dining room and the bedroom, where the training fire was located. The search team continued into the burning bedroom, encountering deteriorating conditions with high heat and no visibility due to heavy smoke.

**Figure C** Interior of fire room in Poinciana.

On the exterior, a second suppression team waited at the front doorway, with two more fire fighters assigned as the rapid intervention crew (RIC), and a third, uncharged 1¾" (44 mm) hose line also was available outside. One fire fighter was stationed on the exterior waiting for orders to ventilate.

With near zero visibility and increasing heat conditions, two of the interior safety officers monitoring the activities of the fire room area later stated that they heard the lieutenant of the search team ask his partner if he had searched the entire room. They heard the answer "yes." Shortly thereafter, one of the safety officers yelled into the fire room asking if the search team was out. Although someone answered "yes," no one knows who replied. The interior safety officer assumed that he had missed the search team's exit from the fire room, as there were several fire fighters present by the dining room. He began to search the rest of the structure in an attempt to find them.

The instructor-in-charge ordered the front window of the fire room to be broken. After the window was broken out, heavy black smoke followed, which ignited very quickly with flames forcibly venting from the window. The suppression crew closest to the fire room applied water in short bursts, but increasing heat and steam forced the safety officers and the suppression crew to back out. Both safety officers were forced to exit the structure, after receiving burn injuries.

The second suppression team was ordered to replace the first team and engage the fire. The second team and an interior safety officer entered the fire room and extinguished the fire.

During this time the instructor-in-charge called the missing fire fighters several times and received no answer.

While the second suppression team was overhauling the fire area, they found a body in fire fighter bunker gear facedown on the floor. Both of the suppression team fire fighters initially thought it was the rescue mannequin, not realizing it was the lieutenant of the SAR team.

After no radio response from the SAR team, the instructor-in-charge ordered a personnel accountability report (PAR) and ordered the RIC to enter the structure and find the SAR team.

The suppression team that found the lieutenant, dragged him to the front window of the fire room, and removed him to the outside. The missing fire fighter was also found inside that window, and he too was removed to the outside. The entire event, from the time the SAR crew entered to when the first of the two fire fighters were located, was under 14 minutes. The two fire fighters died despite working in teams with experienced instructors, two interior staffed hose lines, two interior safety teams, an RIC with its own hose line, a participant walk-though, and other safeguards in place.

# Incident Report

## Poinciana, Florida - 2002

The National Institute for Occupational Safety and Health (NIOSH) investigated the fire. Two separate investigations were conducted by the state fire marshal, one for criminal violations, and an administrative investigation of state training codes. No criminal charges were filed, however the findings included the following:

- "All of the participants stated…they did not have any concerns regarding the conditions of the fire inside the structure and it appeared to them as normal fire behavior."
- Although NFPA 1403 was already required in state code, it was under the environmental laws and so the law enforcement department of the state fire marshal's office did not have the authority to enforce it.
- The fire was started in a room with too much fuel for the size of the room, including a foam mattress that was added after ignition. Flashover was precipitated by too high a fuel load and inadequate ventilation.
- National Institute of Standards and Technology (NIST) determined that the mattress was contributory to considerable smoke production; however in testing, the room flashed over in roughly the same time without the mattress present.

### Post-Incident Analysis Poinciana, Florida

**NFPA 1403 Noncompliant**

- No written preburn plan prepared (4.2.25.2)
- Accountability was not maintained at the point of entry to the fire room (4.5.6)
- Safety crews did not have specific assignments or emergency procedures (4.2.25)
- Fire started near the only doorway in and out of the fire room (4.4.16)
- Excessive fuel loading (4.3.4)
- No communications plan in place (4.4.9)

**NFPA 1403 Compliant**

- Experienced instructors had worked together on training fires before (4.5.1)
- Primary and secondary suppression crews inside with hose lines (4.4.6.2)
- A walk-through of the structure was conducted (4.2.25.4)
- Crews were alerted of the possibility of a victim (4.2.25.1)
- Structure in good condition (4.2.1)

**Other Issues**

- Radio communications less than optimal
- Egress limited by offset turns, a 26" (66 cm) opening, and multiple rooms and turns

## Cardiac Emergencies

Sudden cardiac events are the leading cause of line-of-duty deaths among fire fighters. Each year approximately 45 to 50 percent of fire fighter deaths are caused by sudden cardiac events. In addition to the fatalities, approximately 800 to 1000 fire fighters suffer nonfatal heart attacks while on-duty.

Heart attacks occur when a blood clot blocks a coronary artery and deprives the heart muscle of oxygen. Heart attacks usually occur in individuals with underlying cardiovascular diseases. Sudden cardiac death results from a sudden loss of function of the heart, usually because of a lethal arrhythmia. A heart attack can lead to a sudden cardiac death, and often in the fire service these terms are used interchangeably when citing fatality statistics. This chapter uses sudden cardiac events as an inclusive term that includes all cardiac events that occur during or shortly after firefighting.

Firefighting appears to act as a trigger for sudden cardiac events in vulnerable individuals. A study by a Harvard research team found that fire fighters spend only a small percentage of their time engaged in firefighting activity, but a large percentage of their fatalities occur within a short time after firefighting activity. Based on a national sample of fire fighters, it was estimated that fire fighters spend approximately 1 percent of their time engaged in firefighting activity. Based on the time spent in firefighting and the percentage of deaths that occur shortly thereafter, the researchers calculated that a fire fighter is approximately 100 times more likely to suffer a sudden cardiac event after firefighting than during station activity.

Sudden cardiac events also occur during fire fighter training. In fire fighters above the age of 35 years, approximately 68 percent of fire fighter fatalities during training were the result of sudden cardiac events. A live fire training instructor must understand the factors that increase the risk of sudden cardiac events, and do everything in their control to lessen these risks.

### Risk Factors for Developing Cardiovascular Disease

Risk factors can be modifiable or nonmodifiable. A modifiable risk factor is one that can be minimized, for example through diet, exercise, or modified personal habits. Several nonmodifiable and modifiable risk factors for cardiovascular disease are presented in Table 4-4. Age is an example of a nonmodifiable risk factor. For instance, mates are more likely to suffer cardiovascular disease at a younger age than females; therefore, being over 45 years old is considered a risk factor for males and being over 55 years old is a risk factor for females. Another example of a nonmodifiable risk factor is heredity or family history.

Modifiable risk factors are important because altering them can directly influence a person's likelihood of developing infection or disease, and, in this case, cardiovascular disease. The more risk factors an individual has, the greater the likelihood that he or she will suffer from cardiovascular disease. The good news is that with information and support, and encouragement by coworkers and family, most fire fighters can reduce their risk for cardiovascular disease by following reasonable guidelines for healthy living.

#### Decreasing Risk Factors for Cardiovascular Disease

Cardiovascular disease is a major threat to the health and safety of fire fighters. In order to stay healthy, and address the risk factors for developing cardiovascular disease, a fire fighter should adopt healthy lifestyle habits. In short, to reduce the risk of suffering a heart attack or stroke, it is imperative that fire fighters attempt the following:

- Do not smoke, or quit smoking.
- Follow a regimen of moderate aerobic exercise.
- Eat a balanced diet, avoiding excess saturated fats and simple sugars.
- Maintain a normal body weight.

The risk factors that are influenced by each of the above recommendations are highlighted in Table 4-5. Notice the benefit of physical activity in eliminating or favorably impacting five of the six modifiable risk factors.

### Prevention of Cardiac Emergencies

Live fire training often involves performing strenuous muscular work while wearing heavy personal protective clothing under hot and hostile conditions. This level of exertion can trigger a sudden cardiac event in individuals with underlying cardiovascular disorders. In order to minimize the risk of cardiac emergencies, fire instructors should do the following:

- Be aware of the risk factors for cardiovascular disease.
- Work to ensure that students have medical clearance to engage in structural firefighting.

**Table 4-4 Risk Factors for Developing Cardiovascular Disease**

| Nonmodifiable Risk Factors | Major Modifiable Risk Factors |
|---|---|
| Age | Cigarette smoking |
| Heredity | Hypertension |
| Race | Cholesterol-lipid fractions |
| Gender | Obesity |
| | Diabetes mellitus |
| | Physical inactivity |

**Table 4-5 Recommendations for Decreasing CV Risk Factors**

| Recommendations | Risk Factor Influenced |
|---|---|
| Exercise moderately | Decreased blood pressure<br>Improved lipid (chol) profile<br>Decreased body fat<br>Diabetes (improved glucose tolerance)<br>Eliminates physical inactivity |
| Eat a balanced diet | Improved lipid (chol) profile<br>Decreased body weight<br>Diabetes (improved glucose tolerance)<br>May decrease blood pressure |
| Quit smoking | Smoking |

- Be aware of signs and symptoms of a heart attack.
- Establish incident scene rehabilitation that provides medical monitoring of personnel.

Heart attacks can occur suddenly and be associated with intense symptoms, or they may have a gradual onset. A fire fighter complaining of severe chest pain and radiating pain in the arm is showing signs of a possible heart attack. In less obvious cases, a fire fighter may convey vague information such as needing to rest or not feeling well. It is very important that information of this sort be taken seriously, and that a fire fighter who makes such complaints receives medical attention. In the case of a heart attack, the sooner treatment is initiated, the greater the chance of survival. Perhaps the most important initiative that can be taken to prevent cardiac emergencies is to have an effective incident scene rehabilitation area staffed with dedicated, trained emergency medical personnel responsible for monitoring the medical conditions of participants.

## Incident Scene Rehabilitation

**Incident scene rehabilitation** for live fire training is defined as an intervention designed to lessen the physical, physiological, and emotional stresses of firefighting with a goal of improving performance and decreasing the likelihood of on-scene injury or death. Effective incident scene rehabilitation can mitigate the effects of some of the detrimental physiological problems of firefighting by providing rest, rehydration, and cooling of fire fighters. Incident scene rehabilitation can also help identify medical problems early, and may prevent potentially serious consequences by providing appropriate medical monitoring.

### Goals and Purpose of Incident Scene Rehabilitation

NFPA 1584, *Standard on the Rehabilitation Process for Members During Emergency Operations and Training Exercises*, is the standard for on-scene rehabilitation during training and during emergency situations. The standard indicates that rehabilitation operations are required whenever training exercises pose a safety or health risk to members involved in the training. The primary goal of rehabilitation is to ensure that the physical and mental condition of members operating at the scene of an emergency or a training exercise do not deteriorate to a point that affects the safety of others or that jeopardizes the integrity of the operation. In order to achieve this, the NFPA standard identifies nine guidelines that need to be addressed in establishing incident scene rehabilitation:

1. Relief from climatic conditions
2. Rest and recovery
3. Active and/or passive cooling or warming as needed
4. Rehydration (fluid replacement)
5. Calorie and electrolyte replacement
6. Medical monitoring
7. Emergency medical services (EMS) treatment in accordance with local protocol
8. Member accountability
9. Release

These guidelines play a vital role in improving fire fighter performance and decreasing injuries and death during live fire training, especially those related to heat illnesses and cardiac emergencies. Perhaps most important in addressing heat illnesses and cardiac emergencies are the provisions for cooling, rehydration, electrolyte replacement, and medical monitoring.

#### Cooling

Students and instructors who have been involved in live fire training or have been working in personal protective clothing need to implement cooling techniques to lower their elevated body temperatures. Personal protective clothing should be removed and passive or active cooling techniques should be implemented in conjunction with fluid consumption. The decision on whether to use passive or active cooling techniques depends largely on the magnitude of the individual's heat stress. Active cooling techniques, such as forearm immersion, misting fans, and towels soaked in cool water, provide for greater cooling and a more rapid decline in body temperature. For these reasons, active cooling techniques are preferred in conditions in which individuals are exposed to high heat. Given that some individuals may become overheated in almost any live fire training environment, it is advisable to have these techniques readily available.

After exiting a live fire training structure, fire fighters will often claim that doffing their helmet, hood, gloves, and bunker coat is enough to make them feel cooler. Doffing protective gear does bring the skin in closer contact with cooler air than the training environment, and it provides a perception of the body "cooling down." However, as long as much of the body is still encapsulated in the protective gear, there is limited cooling of the internal body and core temperature is likely to remain elevated. The goal of cooling should be to decrease core body temperature, not just to make the fire fighter feel cooler.

In cases of suspected heat exhaustion or heatstroke, it is critical that aggressive cooling be initiated. Heatstroke is a life-threatening emergency, and if it is suspected, the individual's gear should be removed and the fire fighter should be transported to the hospital immediately. Measures to cool down the fire fighter such as ice packs and cold towels should be taken en route.

#### Rehydration and Electrolyte Replacement

NFPA 1584 indicates that individuals undergoing scheduled events, such as training, should maintain proper hydration and should prehydrate with an additional 16 oz. (500 ml) of fluid within two hours prior to the event. During rehabilitation, fire fighters should consume enough fluid to ensure that they are not thirsty. Fluid intake, beyond what satisfies thirst, may be beneficial given that thirst is an inadequate method for determining the body's hydration status.

Calorie and electrolyte replacement is also required for training that lasts more than three hours or where fire fighters are working for more than one hour. Commonly available sports drinks are a convenient way to provide carbohydrate and electrolyte replacement during training.

Again, it is worth emphasizing the importance of beginning firefighting activities in a well-hydrated state. Rehydration is necessary after strenuous work that causes profuse sweating. However, the fire fighter is put at risk when he or she is not adequately hydrated at the onset of an activity. It is nearly impossible to catch up with the body's fluid needs if starting at a deficit.

### Medical Monitoring

Medical monitoring is a process of monitoring fire fighters who are at risk of adverse health events, such as heat illness or cardiac-related events. Medical monitoring includes a combination of obtaining vital signs, assessing individuals, and applying clinical judgment. Although it is important to monitor vital signs, this alone is insufficient. Vital signs that should be measured by trained emergency medical services (EMS) personnel include heart rate, respiratory rate, blood pressure, and body temperature.

Heart rates can easily reach maximal levels during live fire training. However, heart rate values should return to normal levels during rehabilitation. After 20 minutes of rehabilitation, a heart rate over 100 beats per minute is abnormal and may warrant further medical evaluation. Likewise, respiration rates should return to normal values, about 12–20 breaths per minute following 20 minutes of rehabilitation.

Blood pressure varies considerably among individuals, and the blood pressure response to training can vary widely as well. Systolic blood pressure measurements above 160 mm Hg, or diastolic blood pressure measurements above 100 mm Hg, after 20 minutes of rehabilitation are abnormal and should be continuously monitored or evaluated medically. Hypotension, or low blood pressure, can also be a problem following firefighting activity. The combination of elevated body temperature and sweat loss can cause a low blood pressure. This becomes problematic if pressure is not high enough to adequately profuse body tissues, especially the heart and the brain.

Body temperature is another important variable because elevated body temperature causes several detrimental responses. Body temperature is very difficult to accurately measure in rehabilitation settings. Oral temperatures are often artificially low because of heavy breathing, and the ingestion of cold fluid decreases the temperature of the oral cavity. Handheld tympanic (ear) thermometers are convenient but they often underestimate deep body temperature and they are greatly affected by environmental temperatures. Thus, tympanic temperatures may be low even when an individual has a high body temperature. If temperature is assessed in the field, the value must be interpreted based on the entire clinical picture. Given the difficulties in obtaining accurate measurements, it is certainly possible that a fire fighter with a low measured temperature is still suffering from heat stress. In other words, thermometers deployed in the field may detect individuals with high temperatures that need further examination, but they may also fail to detect individuals who have high temperatures. Thus it is critical that individuals providing rehabilitation consider the possibility of heat stress even in the absence of high measured temperatures.

It is important to monitor vital signs because they provide clues to how a fire fighter is responding to rehabilitation. However, the information gained from monitoring vital signs should not replace the judgment of EMS personnel. A fire fighter should be evaluated by EMS personnel if he or she is not responding in appropriate ways; is acting confused, weak, or overly fatigued; does not appear normal in color or alertness; or is excessively sweating. A fire fighter who is experiencing chest pain, shortness of breath, dizziness, or nausea should be immediately transported to a medical facility for evaluation. Abnormal vital signs may be an indication to transport a fire fighter to a medical facility, but a normal set of vital signs in conjunction with an abnormal clinical presentation should not be reason enough *not to* seek further evaluation or to transport to a medical facility.

# Wrap-Up

## Ready for Review

- Firefighting is dangerous and physically demanding, therefore there are many strains placed on the fire fighter's cardiovascular and thermoregulatory systems.
- Personal protective equipment, high stress, and physical strain all cause stress on the body's regulatory systems.
- Instructors need to consider the amount of heat exposure received by themselves and their students.
- Several interrelated factors affect the physiological responses to firefighting, including environmental conditions, PPE, work performed, individual characteristics, fitness levels, medical conditions, and hydration status.
- Instructors should be aware of the amount of time that participants are in full turnout gear, and should allow time for them to remove their gear and recover.
- Personal fitness (aerobic and muscular) is important to safely and successfully complete firefighting activity.
- Instructors need to ensure the hydration of their students and themselves. Thirst is not an adequate way of measuring a body's need for fluid.
- Watch out for signs and symptoms of heat illnesses and deal with issues immediately before they get worse.
- Cardiac events are the leading cause death in fire fighters in the line of duty. Some risk factors cannot be changed, but modifiable risk factors are particularly important because they can be altered to improve your health and help avoid cardiovascular disease.
- The best way to avoid cardiovascular disease is to not smoke, follow a regimen of moderate aerobic exercise, and eat a balanced diet.
- Incident scene rehabilitation must be established at live fire training. Rehabilitation provides medical monitoring of personnel, time for fire fighters to recover, cool down, and rehydrate.

## Hot Terms

**Core temperature** The body's internal temperature.

**Incident scene rehabilitation** A function on the fireground that cares for the well being of the fire fighters. It includes physical assessment, revitalization, medical evaluation and treatment, and regular monitoring of vital signs.

**Stroke volume** The amount of blood pumped with each contraction of the heart.

**Thermal gradient** The rate of temperature change with distance.

**Thermal tolerance** The body's ability to cope with high heat conditions.

**Thermoregulation** The process by which the body regulates body temperature.

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# Wrap-Up

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# Live Fire Training Instructor *in Action*


As a live fire training instructor you are responsible for ensuring the safety of students. Live fire training presents multiple risks that must be managed. Relative to the physiological responses to firefighting you must be acutely aware of the normal responses to firefighting and the potential for life-threatening events related to heat illness and cardiac emergencies.

**1.** Which of the following factors lead to high cardiovascular and thermal strain during firefighting activity?

**A.** The strenuous and dangerous nature of the work
**B.** Heavy and encapsulating PPE
**C.** Psychological stress
**D.** All of the above

**2.** How does PPE (personal protective equipment) affect a fire fighter?

**A.** It only positively affects a fire fighter, by protecting him or her from direct contact with open heat sources.
**B.** It interferes with evaporative cooling.
**C.** It greatly increases heart rates.
**D.** Both B and C are correct.

**3.** Which of the following is a life-threatening emergency requiring immediate medical attention?

**A.** Heat rash
**B.** Heat cramps
**C.** Heat exhaustion
**D.** Heatstroke

**4.** What is the leading cause of fire fighter fatality during training?

**A.** Heat cramps
**B.** Heat exhaustion
**C.** Heatstroke
**D.** Sudden cardiac events

**5.** What effect does moderate exercise have on modifiable risk factors?

**A.** It only decreases body fat.
**B.** It increases body fat.
**C.** It has a positive impact on several modifiable risk factors.
**D.** It has a negative impact on several modifiable risk factors.

**6.** Which of the following is a goal of incident scene rehabilitation?

**A.** Provide medical monitoring and treatment
**B.** Establish standards for food and fluid replacement
**C.** Provide cooling
**D.** All of the above

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