

Heat Stress Resource Packet  
Naval Safety Center  
Updated 10/2/13  
Ms. Kelsey Leo

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| <input type="checkbox"/> Radakovic, Sonja S. Maric JelenaSurbatovic MajaRadjen SlavicaStefanova ElkaStankovic NebojsaFilipovic Nikola. (2007). Effects of Acclimation on Cognitive Performance in Soldiers during Exertional Heat Stress. <i>Military Medicine</i> , 172(2), 133-136.  | 26   |
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## Hit by the PENSACOLA HEAT

BY ENS. JASON HIRZEL

**F**or a wide-eyed ensign stationed in Pensacola, summer offered great flying conditions. I enjoyed sunny days of zooming through a big, blue sky while cloud-surfing and enjoying a beautiful coastal view. What more could a student NFO ask for? However, coming from California, where the summers are moderate and pleasant, I failed to realize the intensity of the summer heat in Florida. If Pensacola isn't overcast with an impending thunderstorm, then it's hot and humid. You just want to sit inside with a cold beverage and max air conditioning. Add to the heat our full flight gear, a hot parking ramp, and a T-6A canopy that when closed emulates the greenhouse effect, and your chances for a heat-related incident are real.

I had recently returned from a weekend cross-country flight to Santa Fe, N.M., and was scheduled for two flights on Monday. I went home to begin flight planning. I pounded caffeine drinks and snacked to stay focused. I didn't drink water or eat a healthy meal — I wanted to get to bed at a reasonable hour.

The next day the sun was beating down, the temperature was more than 100 degrees and the humidity near 100 percent. The tarmac was hot, with sauna-like conditions in the cockpit; the Pensacola summer was en fuego.

With full flight gear, including G-suit and harness, I was ready to walk to the plane with my instructor pilot. The heat was more intense than expected. Sweat beads started to form, and I had a river streaming off my nose even before I got to the aircraft. I shrugged off having my gear sweat-soaked and continued with the checklists. I was confident that I'd cool down after engine start when the air conditioning came on.

We were delayed with clearance delivery for a few minutes. I noticed how much I had sweated but continued to press forward. As the aircraft left the chocks, we heard a loud clunking noise and suspected a nosewheel-steering problem. This would be yet another delay and would require maintenance troubleshooting.

While we waited for maintenance, the heat continued to beat down on me. I felt dizzy and very dehydrated. We were instructed to shut down the engine and get another aircraft; this one was not fully mission capable. My IP instructed me to start on the preflight checklist on the newly assigned aircraft, and he would go inside to complete the necessary paperwork.

I ran to the new plane to get everything set up, not wanting to disappoint my IP. Running to the plane in the heat was a mistake. Once I got there, I was breathing heavily, sweating profusely and felt even dizzier. Heat had never been a problem for me in the past, and I didn't want to stop because I felt hot.

My instructor arrived at the plane, and we started the before-exterior checklist. As I read the checklist items, I felt weak in the legs. My head was spinning, and I could barely breathe. But, I didn't want to wimp out. I thought, "It's just a little heat, I can get through this." Then I started to slur my speech; my knees buckled. The heat delivered its final blow as my instructor grabbed me, took me off the wing, and had a maintenance golf cart drive me into the air-conditioned building.

Our medical folks diagnosed me with a case of heat asthenia, a lesser case of heat exhaustion. I was told to drink twice the usual amount of water and supplement with sports drinks.

Heat illness is a serious condition and can kill if not recognized in a timely manner. Had we actually taken off, I would have been a liability to the aircrew. I would not have been a functioning crewmember, which would have put me and my instructor in danger.

I realize my situation is not nearly as severe as conditions can be on aircraft carriers or the Middle East desert, but the lesson remains the same: Stay hydrated, eat healthy, get a good night's sleep and always be aware of the heat. 

ENS. HIRZEL FLIES WITH VT-10.

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# Dehydration, Heat Stress In-Flight? Not Me!

## *Dehydration Hazrep*

*A T-39 naval flight student completed 30 minutes of intense aerobic exercise the night before a flight. Following her exercise session, she ate a six-inch sandwich and drank eight ounces of water at 2000. She went to bed at 0230, woke up at 0700 and had an eight-ounce serving of yogurt for breakfast at 0800. At 1100, she ate another eight-ounce yogurt and drank 10 ounces of iced tea. The preflight brief was at 1230 for a 1430 takeoff. During the flight, at about 1530, she had hot flashes and felt disoriented. A few moments later, the aircraft banked as she looked out the cockpit. She immediately felt worse, and told the MC she felt like passing out. The MC called a knock-it-off and RTB.*

*During the flight home, her symptoms didn't get any better, and she had difficulty communicating with fellow aircrew. Once the aircraft landed she was seen by a flight surgeon. The lab results indicated she had urinary ketones, which are normal by-products of breaking down fat for energy. The presence of ketones in the urine was due do to inadequate caloric intake. This resulted in her inability to maintain an optimal blood-sugar level, and is significant for two reasons. First, the brain's primary source of energy is sugar, and an inadequate intake will cause a decline in mental performance and eventually incapacitation. Second, about 30 percent of the average person's fluid intake comes from food. The combination of low caloric intake, low fluid intake, and intense aerobic exercise contributed to dehydration.*

## *Heat Stress Hazrep*

*During an FA-18 flight, the cabin-flow valve, which regulates the environment-control-system (ECS) flow to the cockpit, was found stuck open. This reduced airflow to the avionics and triggered the AV AIR HOT caution. Once the ECS was secured using AV AIR HOT procedures, the lack of cabin airflow, combined with a high OAT/heat index and the greenhouse affect of the bubble canopy, resulted in an estimated cockpit temperature of more than 130 F.*

*This incident underlines how important it is that aircrew recognize heat-related illness. The immediate recognition of symptoms directly contributed to their expeditious recovery and minimized aircrew exposure to a dangerous environment. Because of frequent operations in unusually warm and humid environments, all aircrew should make themselves as familiar with the symptoms of heat-related illness as they are with hypoxia.*



**BY CDR. DON DELOREY**

**W**

hat do these hazreps illustrate? They show the effects of dehydration and heat stress on the aviator in the flight environment.

The main component of the human body is water: about two-thirds of your body weight is water, which means an individual who weighs 170 pounds will have more than 10 gallons of water in their cells, around the cells and in the bloodstream. Clearly, water has an important role in the body.

While many pilots are aware of the term “dehydration,” very few take appropriate actions to make sure they are well hydrated before, during and after flight operations. Why is this? It appears that most pilots are unaware of the symptoms and devastating effects associated with dehydration, which can increase the risk of a mishap, even during a mildly warm day.

What causes dehydration? It can be caused by many factors, such as inadequate fluid intake, a dry environment in the aircraft, excess caffeine and antihistamines. Hot cockpits and flight lines also can cause dehydration. A blistering hot 130-degree ramp at Yuma, Ariz., is an obvious cause of dehydration. However, what about the less obvious cause: the 72-degree cockpit? The average humidity in the cockpit is quite low, which can result in a substantial amount of lost fluid.

### **Dehydration and performance**

Dehydration can result in decrements in physical and cognitive performance. Each of these can occur when two percent or more of body weight is lost because of unreplaced water or water restriction, heat,

and/or physical exertion. Long-term effects of dehydration can include wrinkled skin, impaired memory function, dry hair, brittle nails, constipation, and susceptibility to colds and sinus infections (because of extremely dry nasal passages).

Common signs of dehydration are headache, fatigue, cramps, sleepiness, and dizziness. You must be aware that unreplaced water losses of two percent of your body weight will degrade your ability to regulate heat. At three percent loss, there is a decrease in muscle cell contraction times. When fluid losses equal four percent of body weight, you'll have a five-to-10 percent drop in overall performance, which can last up to four hours.

Another physiological factor that can be associated with dehydration is heat exhaustion, which consists of the following three stages. The transition from one stage to the next can be very evident, hardly noticeable, or not evident at all.

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**Heat stress (body temperature, 99.5 to 100 F) reduces:**

- Performance, dexterity, and coordination
- Ability to make quick decisions
- Alertness
- Visual capabilities
- Caution and caring

**Heat exhaustion (101 to 105 F) symptoms are:**

- Fatigue
- Nausea/vomiting
- Giddiness
- Cramps
- Rapid breathing
- Fainting

**Heat stroke (>105 F) symptoms are:**

- Body's heat control mechanism stops working
- Mental confusion
- Disorientation
- Bizarre behavior
- Coma

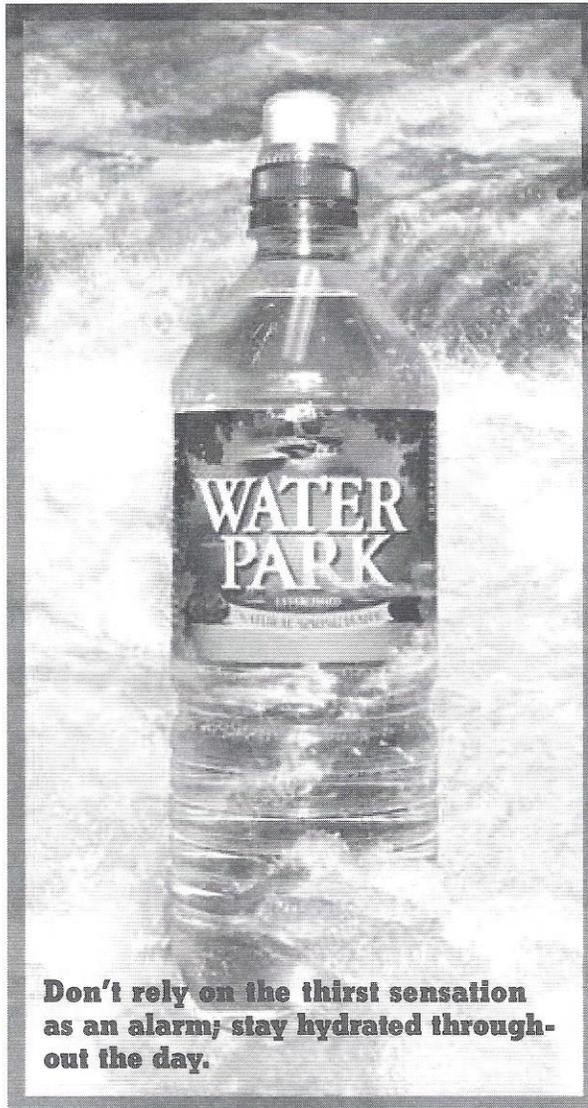
**Preventing dehydration**

You should drink two to four quarts of water every 24 hours. However, as each person is physiologically unique, this should be used only as a guide. You also can apply the eight-cups-a-day rule, with each cup of water being about eight ounces. By drinking eight cups of water a day, you'll consume 64 ounces (two quarts).

It also is important to monitor your hydration status. Most people will become thirsty when they have a one-and-a-half-quart deficit (about a loss of about two percent of total body weight), which will trigger the thirst mechanism. You might believe the thirst mechanism is the proper cue to drink more water; however, the thirst mechanism arrives too late and too easily is

turned off. A small amount of fluid in the mouth can turn off the thirst mechanism, which will further delay the replacement of body fluids.

Remember that the environmental temperature and humidity, as well as personal lifestyle and individual physiology, will influence the amount of water you need to prevent dehydration. If you do not maintain good situational awareness (SA) of your water requirements by knowing your flight environment and personal physiological status, you can progress to heat exhaustion.



**To help prevent heat exhaustion.**

- *Drink cool water.*

Don't rely on the thirst sensation as an alarm; stay hydrated throughout the day.

Limit excessive intake of caffeine and alcohol beverages.

Hydrate before, during, and after exercise, as exercise can result in large amounts of body fluid loss.

Note that acclimation to a major change in weather takes about one to two weeks.

Monitor personal effects of aging, recent illness, diarrhea, or vomiting.

Monitor your work and recreational activity; if you feel lightheaded or dizzy, call it a day.

For the average person with a moderate exercise program, the loss of salt and electrolytes in extreme heat and exercise conditions is usually not a factor, as the typical American diet takes care of the loss.

Bottom line, remember to hydrate—your body will thank you. 

CDR. DELOREY IS THE AEROSPACE PHYSIOLOGIST AT THE NAVAL SAFETY CENTER.

# Heating Up

The Wet-Bulb Globe Temperature Index (WBGTI) takes into account four variables: air temperature, humidity, radiant heat and air movement. This reading gives a more accurate measurement of heat stress than any one reading alone.

**BY CAPT. NICK DAVENPORT, MC**

**T**he body can only function well and survive within a very narrow range of temperatures. This becomes a problem when we have to exercise or perform heavy manual labor, since the muscular activity and work done produce heat as a by-product. Just as a car engine straining to climb a grade can overheat, boil its radiator and seize up, humans figuratively can do the same.

Most cars dissipate heat by drawing cooler air over the radiator coils (convective heat loss) and to a much lesser extent by radiating heat (radiant heat loss) to the surrounding environment. "Radiators" should really be called "convectors" because that's primarily how they act. We'll call our heat loss mechanisms "heat exchangers."

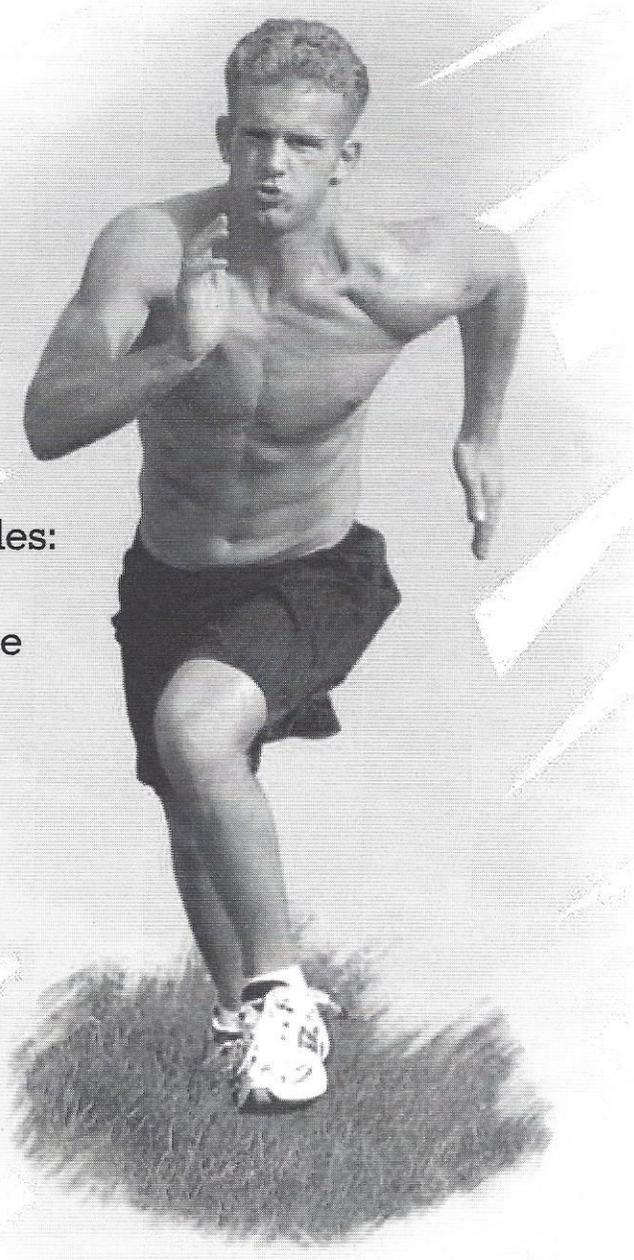
Our heat exchangers, which dissipate excess body heat, are much more sophisticated than your car's. The lungs, bare skin, and sweat glands dissipate heat. Air drawn into the lungs is heated to body temperature and saturated with water vapor, both of which cool the air passages and lungs while the heated humidified air is exhaled (convection, followed by evaporation). Your dog has figured this out, which is why he pants with his wet tongue hanging out on a hot day.

Sweat will evaporate from the skin as long as the

humidity and ambient temperature are low enough, which is why you stand sweating in front of that fan in the gym after your workout. This is the chief method of heat exchange during exercise. But guess what, if the air temperature is 98.6 F, and the humidity is 100 percent, you've now lost all ability to lose heat by convection and evaporation.

You'll notice that convection combined with evaporation depends on having plenty of water available, which is why hydration is so important when exercising in hot conditions. Because these are the primary heat exchangers in exercise, lots of water is required. Thirst may not be a reliable indicator of fluid need. That's why monitoring the urine color is a better indicator; a pale color is best.

As long as the surrounding temperature is less than



98.6 F, the skin successfully can radiate heat. When you are in a room temperature environment and not exercising, you are experiencing the prime method of heat exchange. While standing in the sun, you're absorbing radiant heat. You're now gaining additional heat.

Conductive heat loss is possible by exposing the skin to cold surfaces. Jumping in a cold pool on a hot day causes heat loss by conduction. Cold objects applied to the skin, such as putting ice packs under the armpits and on the groin area, do the same thing. In cold water, hypothermia can develop rapidly because of the excellent heat-conducting properties of water (about 25 times greater than air).

Even with normal exercise, the body core temperature can rise a couple of degrees. We typically react by panting, sweating, and standing in front of a fan or air conditioner to cool off. When we speak of heat acclimatization, we're talking about the body getting as efficient as it can at employing these different heat exchangers. All our heat exchangers can max out when conditions of high work load combine with elevated environmental temperatures and high humidity. Relative dehydration and loss of electrolytes such as salt also can occur when working in hot climates over several days. Many health conditions (obesity, deconditioning), alcohol, hangovers, and medications (antihistamines, blood pressure medications) adversely affect our heat exchangers, making us more susceptible to heat injury. Exercising in sweat suits or heavy clothing to lose weight only results in increased dehydration and risk of heat injury.

That strange gadget, called the wet bulb globe temperature (WBGT) meter, is designed to measure the environment to see if the heat exchangers of the body can liberate enough heat during exercise. Once the WBGT gets high enough, the dreaded black flag is raised, indicating the environment can't accept the heat humans generate when exercising. It's not a motivation or a "gut it out" sort of thing, it's just plain physics. These evaporative, convective, radiative and conductive heat-exchanging mechanisms just can't keep pace with the heat generated, and body temperatures start to rise. When you exercise in black-flag conditions, you start to cook. LCdr. Sparks in his "Run or Fly" article (p. 7) provided an excellent description of what that feels like.

Heat cramps occur as fluid and electrolytes are lost from the body in hot climates while exerting the muscles. Extremity and abdominal muscles can become irritable and may go into spasm and fail to relax after contraction, causing painful cramps. Hydration, rest,

cooling, and stopping the exercise typically relieve heat cramps, but it may take two-to-three days to restore body fluid and electrolyte equilibrium. Heat cramps may not occur first, so they are unreliable as a warning sign. Most animals will sensibly stop at this point, but horses and humans can be motivated to press on.

Heat exhaustion occurs as the process continues, and the core temperature rises. The brain realizes it's starting to cook, and marshals all the body resources to get rid of the excess heat. Respiration increases and panting ensues. The heart circulates blood faster, veins and arteries dilate, and fluids are shifted from the blood into the sweat glands and membranes of the airways. The skin may be clammy, moist and pale. Nausea, vomiting and diarrhea may follow. If exercise is not stopped and hydration isn't given, heat exhaustion can progress to heat stroke.

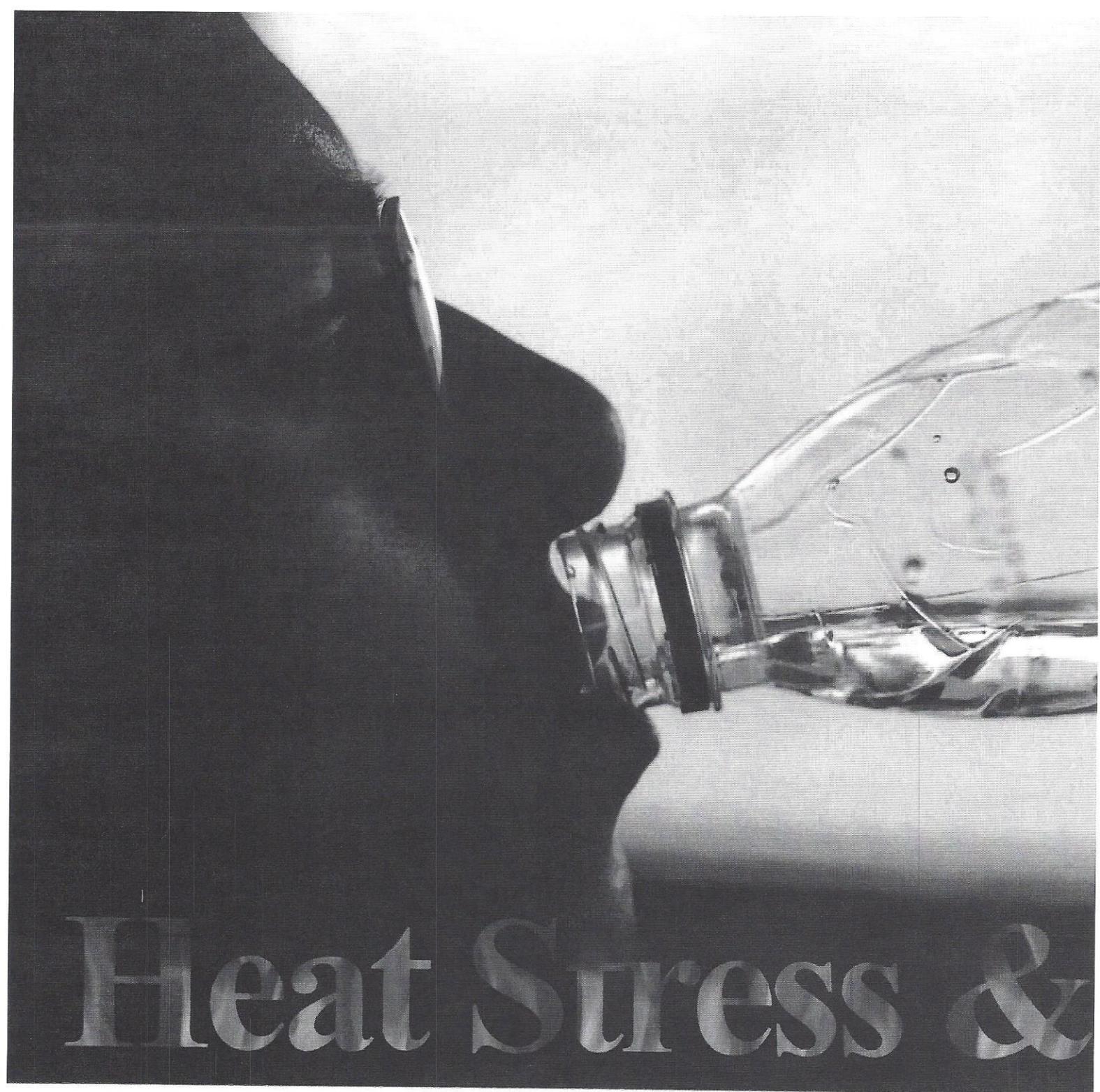
HEAT STROKE SIGNALS THE FINAL PHASE, and begins when the brain loses its ability to regulate the body's heat exchangers. Absence of sweating and mental-status changes are key features. The individual is confused, delirious or even comatose, and can no longer assess the dire situation and react appropriately. The core temperature may be above 105 F and spiraling higher. From a combination of excessive temperature, dehydration, and metabolic byproducts, the regulatory circuits fail. As water is lost from the blood and tissues, the blood thickens and tissues become severely dehydrated. Blood is shunted away from other vital organs such as the kidney and digestive organs in the gut. Kidney failure may begin as these high-energy organs starve for blood. Muscles may break down, showering the kidneys with muscle proteins, and plugging the kidneys (rhabdomyolysis). The skin may be hot and pale.

This condition is a true medical emergency, and rapid cooling and IV hydration are required to save life. Immediately get the individual in the shade, spray with cold water, fan air over the body and apply ice. The neck, armpits and groin typically are chosen first because large arteries and veins cross these areas that are directly cooled by the ice.

Don't forget to call 911.

Bottom line, follow LCdr. Sparks' advice and don't exercise in black-flag conditions. The heat experience you have today may keep you off tomorrow's flight schedule. 

CAPT. NICK DAVENPORT IS THE HEAD, AEROMEDICAL DIVISION, NAVAL SAFETY CENTER.



# Heat Stress &

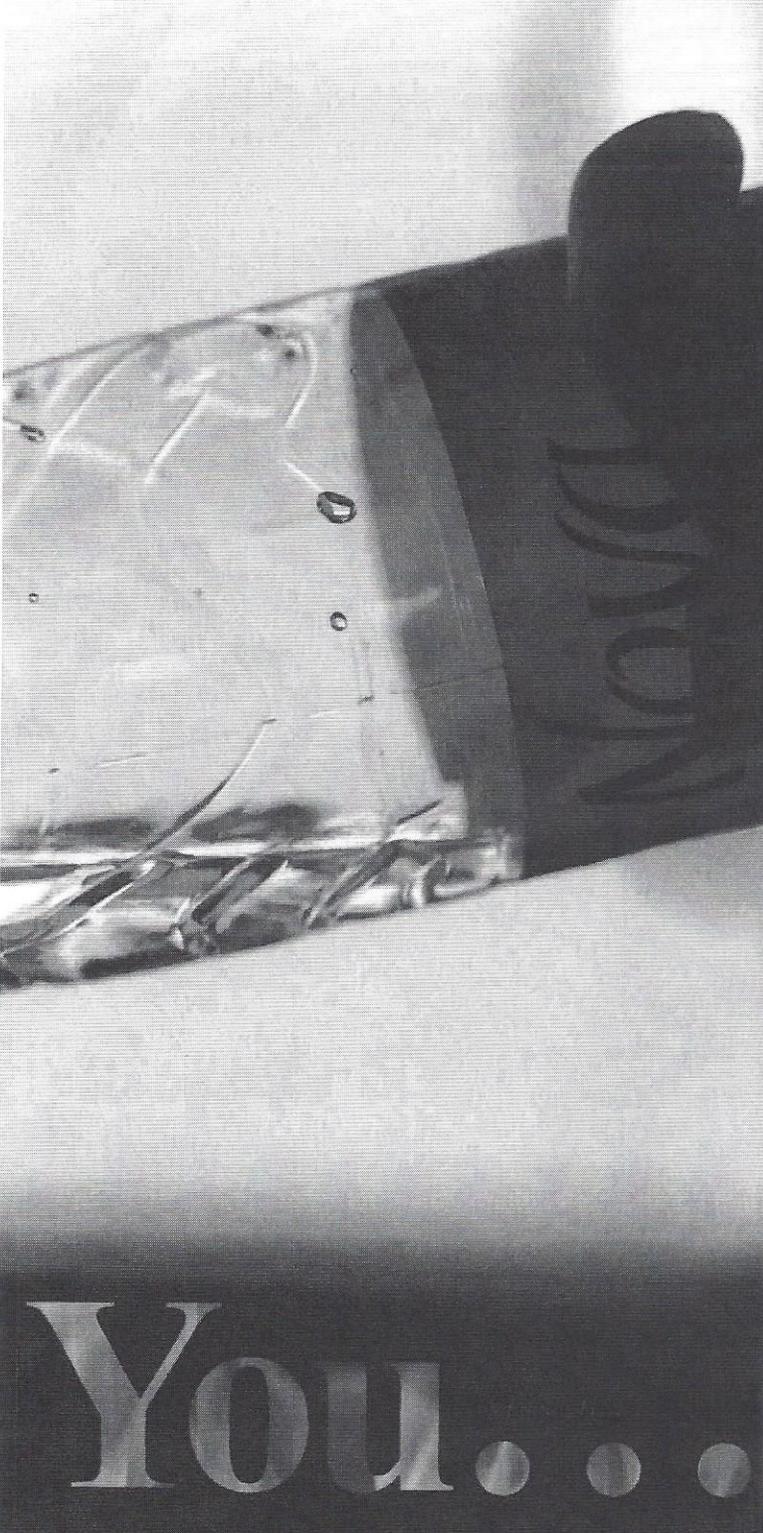
**H**eat stress can cripple you and place your mission at great risk. Who would have thought that something as unexciting as overheating could put you down for the count, or worse, even kill you?

Heat stress includes many conditions where the body is stressed by overheating. There are several different causes of heat stress including high temperatures, heavy workloads, lack of proper hydration and the type of clothing being worn. Roughly three-fourths of the stored energy the body draws on

during activity converts to heat rather than motion. The harder you work, the more heat you create. In order to prevent the body from overheating, one must understand how it cools off.

### **The Body Has Built-in Air Conditioning**

There are four ways the body rids itself of heat. This transfer takes place through radiation, evaporation, convection and conduction. Radiation occurs when the body turns heat into electromagnetic waves and the body simply radiates the heat into the air around it. Evaporation is what cools you down when



**The sun beats down forcing every possible drop of perspiration out of your body. You keep going, easily ignoring what is about to happen next, as it sneaks up with little fanfare.**

**You are just about to be taken over by heat stress.**

*Left: SrA Richard Aceves, a security forces journeyman deployed from the 163rd Air Reserve Squadron, March AFB, CA, to the 363rd Expeditionary Security Forces Squadron (ESFS), keeps hydrated while on patrol.*

*USAF photo by SSgt Matthew Hannen*

transferred from the body. This lowers the core body temperature. Sometimes this internal air conditioning system can have adverse affects such as impairing strength and dulling senses. By increasing the blood flow to the body surface, the volume of blood carrying oxygen to muscles, brain, and other internal organs is decreased, which may cause fatigue, blurry vision and diminished alertness. The loss of water volume may thicken the blood, making the heart pump harder. Prolonged sweating reduces the electrolytes that the body needs for proper muscle function. The body's cooling system can even shut down under extreme stress, allowing the body temperature to continuously rise.

### **A Hot Situation Can Always Get Hotter**

How many times have you said, "I'm okay, just a little hot"? Well, a "little hot" can go a long way. You simply assume you are feeling a bit ill due to the heat, but you are sweating and that will cool you down, right? Wrong. If you don't replace the water in your body, you may soon become confused and even collapse. Symptoms of heat stress can vary in each individual. Early symptoms of heat stress include dizziness, headache, dry mouth, unsteadiness and muscle pain. Later stages may feature high temperatures, confusion, blurry vision, weak or rapid pulse, convulsions or coma. If you recognize these symptoms, you need to move to a shaded area, drink water, and seek medical attention. The number one defense against heat stress is proper hydration at all times.

**Heat stroke** is the most serious problem faced by individuals in hot environments. It is a definite, no doubt about it, medical emergency. It is caused by the body's failure to regulate your core temperature. In other words, your internal air conditioning shuts down and the heat just keeps rising. Sweating may stop completely and the body temperature rises well over 104 degrees F. Symptoms can range from confusion to coma. Until a medic can tend to the victim, he or she should

you sweat. Convection and conduction happen after radiation and evaporation. Convection is when the body's heat passes into the air and vapors surrounding the body. Conduction is the transfer of heat through physical contact.

When you are hot, the body tells the brain that its core temperature has risen higher than the normal 98.6 degrees F. The anterior hypothalamus, in the brain, acts like a thermostat for an air conditioner. It signals the body to open up blood vessels near the surface of the skin so that heat can be

be moved to a cool or shaded area and doused in lukewarm water – think of it as artificial sweat cooling down the body. The body should be fanned to speed up the cooling effect. In an emergency, remember to cool first and transport later; if the body temperature is allowed to remain high, brain and vital organs will be damaged. Heat stroke may first start as heat exhaustion or heat cramps. Anyone suspected of heat stroke must see a doctor as soon as possible as his or her condition will deteriorate quickly.

**Heat exhaustion** happens when you are extremely fatigued and sweating profusely. What has happened inside the body is that it is basically giving out more water than it receives. Nausea, weakness and a headaches signal that the body’s water reservoirs are running on “E.” The pulse rate may become rapid (120-200 beats per minute) and the body temperature may actually be lower than normal. With heat exhaustion the body’s heat balance mechanism is still functioning, but may shut down very soon. The victim should rest, cool down, and drink cool water. Severe cases of heat exhaustion can even lead to loss of consciousness. Both heat exhaustion and heat stroke can easily reoccur as they weaken the temperature regulating system for a long period of time.

**Heat cramps** are painful spasms in muscles, primarily in the arms, leg and stomach areas. Heat cramps occur when the body loses too much salt. Tired muscles – those working very hard – are the most susceptible to cramping. They can cramp during or after an activity. Replacing missing salts is very important during hot weather activities. Cramps may occur in combination with heat exhaustion. A doctor may decide that an intravenous saline solution is necessary in extreme cases.

**Heat syncope** is commonly known as fainting. It is easy to tell when someone has fainted, but why did they faint? It usually happens when a person has to stay extremely still for a long time in a hot environment that they are not used to yet. Movement is the main ingredient in preventing fainting, though this may not always be an option in certain situations. Fainting victims usually recover quickly, though they need rest and water to prevent it from happening again.

**Heat rash** is known by many as “prickly heat.” It will make you very uncomfortable, unable to concentrate, and very itchy. It has been described as something that “drives a person absolutely nuts.” Left untreated, heat rash may result in a skin infection. Heat rash occurs in hot, humid environments where the skin stays damp. Keeping the skin dry and clean is the best prevention for heat rash. Skin powder and topical medications can provide relief and some victims of heat rash may be placed on an antibiotic.

Temperature in Degrees F.

| Relative Humidity | 70 | 75 | 80 | 85  | 90  | 95  | 100 | 105 | 110 | 115 | 120 |
|-------------------|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|
| 0%                | 64 | 69 | 73 | 78  | 83  | 87  | 91  | 95  | 99  | 103 | 107 |
| 10%               | 65 | 70 | 75 | 80  | 85  | 90  | 95  | 100 | 105 | 111 | 116 |
| 20%               | 66 | 72 | 77 | 82  | 87  | 93  | 99  | 105 | 112 | 120 | 130 |
| 30%               | 67 | 73 | 78 | 84  | 90  | 96  | 104 | 113 | 123 | 135 | 148 |
| 40%               | 68 | 74 | 79 | 86  | 93  | 101 | 110 | 123 | 137 | 151 |     |
| 50%               | 69 | 75 | 81 | 88  | 96  | 107 | 120 | 135 | 150 |     |     |
| 60%               | 70 | 76 | 82 | 90  | 100 | 114 | 132 | 149 |     |     |     |
| 70%               | 70 | 77 | 85 | 93  | 106 | 124 | 144 |     |     |     |     |
| 80%               | 71 | 78 | 86 | 97  | 113 | 136 |     |     |     |     |     |
| 90%               | 71 | 79 | 88 | 102 | 122 |     |     |     |     |     |     |
| 100%              | 72 | 80 | 91 | 108 |     |     |     |     |     |     |     |

How To Use Heat Index: 1. Across top locate Temperature; 2. Down left side locate Relative Humidity; 3. Follow across and down to find Apparent Temperature, and 4. Determine Heat Stress Risk below.

| Apparent Temperature | Heat Stress Risk with Physical Activity and/or Prolonged Exposure |
|----------------------|---|
| 90° to 105°          | Heat cramps or heat exhaustion possible                           |
| 105° to 130°         | Heat cramps or heat exhaustion likely, Heatstroke possible        |
| 130° and up          | Heatstroke highly likely  |

Source: National Oceanic & Atmospheric Administration

**Heat stress** can show itself in many different ways ranging from fatigue to collapse, dehydration to vomiting. Heat stroke, heat exhaustion, heat cramps, fainting and heat rash are all very dangerous results of the body overheating. Heat stroke is the most dangerous level of heat stress and can cause brain damage, organ failure and even death. Heat rash is the least dangerous level of heat stress, causing lack of concentration and possible skin infections.

### Staying Cool Requires Planning

The body efficiently manages heat when it is fully hydrated, physically fit, acclimatized, well nourished, and well rested. Each individual body deals with heat differently. Those that are younger and more physically fit are less likely to be hit by heat stress. Individuals with heart, lung or kidney disease, diabetes and those taking medications are at more risk. Caffeine heightens the risk and is often used by many people to jump start their mornings. You are more likely to experience heat stress when first exposed to a new environment and the job is physically demanding. Someone who has not spent a lot of time outdoors may find themselves facing heat stress on their first call out in a heat wave. Once a person has experienced heat stroke or exhaustion, he or she is very susceptible to a second attack.

How hot is hot? It’s not just the air temperature you should be watching. There are four environmental characteristics that influence how “hot” it is: air temperature, direct sunlight, humidity, and wind speed. Direct sunlight on bare skin can increase the body’s temperature and cause the risk of sunburn. Full sun can be equivalent to a 13 degree increase in air temperature. High humidity decreases the sweat evaporation rate, slowing cooling. Lack of wind can reduce the evaporation rate, also. Air movement affects the body’s convective heat

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transfer; cool winds reduce heat stress, hot winds increase stress.

Drinking water to replace fluid loss is top on the list of medical and governmental prescriptions to combat risk of heat stress. Different people in different situations need different amounts of water. If you are feeling thirsty, you may have already lost two percent of your body's needed water supply. Drink before and after you begin a mission, drink during physical activity and drink often. Military guidelines recommend drinking one quart of water or more per hour under moderate conditions, a little at a time every fifteen minutes. While you should always drink the recommended water for your activity and the ambient temperature, avoid too much icy water being ingested too quickly; you may become ill. As activities or weather conditions become more severe, water intake should increase accordingly. If water is in limited supply, physical activities should be limited, if possible, to early morning, late evening, and night. Cool water is preferred over icy water, and the use of commercial electrolyte drinks are discouraged by the USAF Flight Surgeon's Guide. Water becomes the most important thing when temperatures soar – always have access to water. A body cannot "learn" to do without water, and we cannot teach ourselves to need less water in hot weather.

Maintaining acclimatization to the area is very important. It can take up to two weeks to become physically accustomed to heat and activity levels. The body can "forget" its acclimatization in thirty days, so continued acclimatization must be a priority. Remember, start out slow and easy and add a little more activity with time. When it comes to meals, they should be cool, with the heaviest meal of the day served in the evening. Rest after the noon meal is often helpful in hot

weather, giving time for the digestive system time to use adequate amounts of blood flow before it is diverted to the skin surface.

Good physical condition and proper work schedules are helpful in preventing heat stress. A person becomes more susceptible to heat-related illness when they are overweight, have infections or fever, suffer from heat rash, sunburn, fatigue or have had a prior heat illness. Immunizations can cause adverse reactions, such as fever, that affect the body's ability to sweat and cool down. The type of clothing you are wearing can help or hinder perspiration and the cooling of the body. Always wear the least amount of clothing permissible, except when in direct sun. Clothing should be loose and not restrict circulation of air movement over the skin.

The requirements of military operations often result in lack of sleep and missed meals, making it easier to suffer from heat stresses. According to the USAF Flight Surgeon's Guide, heat-stressed subjects exhibit shorter simple reaction times, higher error rates, neglect of secondary tasks, diminished capacities for learning, and slower responses to unusual events. Memorize the signs of heat stress; learn to recognize them in yourself and others. If you are in the heat and begin to feel ill, chances are that you are overheating. Learn to pace yourself, work more efficiently by slowing down and being able to complete the job. Take adequate cooling down periods – in the shade – if you can. The most important thing you should do is stay hydrated. Pay close attention to those around you; it is often easier to spot symptoms of heat stress in others than in yourself.

A little preventative maintenance and a little knowledge can protect you and those around you. Drink lots of water, keep aware, and watch out for your buddies.

## Symptoms of and Personal Habits Influencing Heat Stress

**HEAT STROKE:** Mental confusion, delirium, shortness of breath, loss of consciousness, convulsions, even coma. Sweating sometimes completely stop, skin is hot and dry and body temperature rises over 106 degrees F. Skin may be red, mottled or blue in appearance.

**HEAT EXHAUSTION:** Excessive sweating, weakness or fatigue, giddiness, nausea, or headaches. Clammy, moist skin and pale complexion.

**HEAT CRAMPS:** Painful spasms of muscles in arms, legs, and/or stomach.

**FAINTING:** Temporary loss of consciousness for a short period of time.

**HEAT RASH:** Itchy rash. Causes lack of sleep, distraction, and loss of ability to concentrate.

**UNACCLIMATIZED TO THE CLIMATE:** Full acclimatization takes 7-14 days of at least 2 hours of supervised exercise in the heat.

**BODY CONDITION:** An overweight or fatigued body cannot easily dispel body heat.

**FOOD CHOICES:** A heavy meal of hot food puts unnecessary stress on the body, adding heat and redirecting blood flow to the digestive tract.

**CLOTHING:** Tight clothing causes heat to be trapped close to the body. Clothing should be loose so that air can move freely over the skin.

**JUST SAY NO:** Alcohol and drugs, legal and illegal, increase your chances of experiencing a heat related illness. Alcoholic beverages decrease body reactions, while many drugs inhibit sweating and impair heat loss.

**ILLNESS:** If you are already ill, your body is already working hard to repair itself. Fever, colds, allergies, and gastrointestinal problems can affect heat dissipation, sweating, and body reactions.

# Misdiagnosis of Exertional Heat Stroke and Improper Medical Treatment

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**ABSTRACT** Exertional heat stroke (EHS) is the most complicated and dangerous amongst heat injuries that can lead to irreversible injury and even death. Early diagnosis and treatment are therefore crucial determinants of the patient's prognosis. The following case report depicts a soldier who presented primarily with confusion and behavioral changes during physical exercise and later lost consciousness. He was misdiagnosed by the field physician as suffering from supraventricular tachycardia, was treated as such and only diagnosed as suffering from EHS later in the emergency room. Our main aims are: to highlight the possibility of misdiagnosis of EHS even among trained physicians, to describe the main symptoms of EHS, and to emphasize the importance of early diagnosis and proper treatment.

## CASE PRESENTATION

A 19-year old previously healthy infantry soldier participated in a 3-km march, carried out under a heavy heat load (temperature 35°C, relative humidity 50%). During the last kilometer of the march the soldier demonstrated behavioral changes: he was irritable, threw rocks, and had slurred speech. He was therefore transported to the base infirmary, while still walking. A few minutes after his arrival to the infirmary he collapsed. The physician observed an incontinent and pale patient, still breathing, with tachycardia (180–210 bpm), decreased blood pressure (80/40 mmHg), and responding to pain. The patient's temperature was not measured. He was connected to a cardiac monitor, which showed narrow complex tachycardia. Suspecting a supraventricular tachycardia, the physician administered a single electric shock that did not change the patient's electrocardiogram (ECG). The patient was given intravenous normal saline and was transported to the nearest hospital.

On arrival to the emergency room (ER) around 20 minutes later, the patient was irritable and uncooperative. A rectal temperature ( $T_{re}$ ) of 41°C was measured. The patient's ECG showed sinus tachycardia, and his blood pressure was in the normal range (128/67). Diagnosed as suffering from exertional heat stroke (EHS), he was cooled by ice water and fanning and was given midazolam, intravenous fluids, and Dextrose 10%. Laboratory results on admission to the ER showed mild acute renal failure (Creatinine 1.88 mg/dL), mildly elevated hepatic transaminases (Alanine transaminase [ALT]-57 U/L, Aspartate aminotransferase [AST]-55 U/L), hypophosphatemia (0.2 MMOL/L), normal coagulation (INR = 1.35), and an elevated Creatine phosphokinase (CPK)-563 IU.

The patient was hospitalized in the intensive care unit. After his body temperature returned to normal values the patient's neurological symptoms resolved, as did his tachycardia. Renal function returned to normal values within 12 hours from admission after proper rehydration. CPK values

increased to a peak of 1800 IU 2 days after the injury and returned to the normal range within 3 days after treatment with fluids and bicarbonate. During the next few days after the injury, the patient developed hepatic damage that was expressed by elevated transaminases (peak levels of AST and ALT 591 and 584 U/L, respectively) and a coagulopathy that was expressed by INR values of 1.98. He was treated with N-acetyl-cystein and vitamin K.

The patient was released from the hospital with both clinical signs and laboratory tests normal, 4 days after admission. He was given a temporary medical profile according to the Israeli Defense Forces criteria for post-heat stroke soldiers, and was not allowed to participate in any physical training. Seven weeks after the injury, he underwent a heat tolerance test (HTT) in our institute according to an accepted protocol<sup>1</sup> to determine his ability to resume his military duty and was diagnosed as heat intolerant. Three months later, the patient underwent a second HTT and was found to be tolerant to heat and fit for a gradual return to military duty.

## DISCUSSION

EHS occurs during or after physical exercise when an individual's heat production exceeds his ability to dissipate it. It is defined as a situation in which body temperature rises to such a level that it inflicts tissue damage and causes a characteristic multisystem syndrome.<sup>2</sup> The EHS severity depends on the peak temperature and the duration of hyperthermia.<sup>3</sup>

Most cases of EHS occur in healthy, highly motivated young individuals who exert themselves beyond their physiological abilities.<sup>4,5</sup> Risk factors for EHS occurrence can be categorized into inherent personal factors, environmental factors, and activity-related factors as detailed in Table I.<sup>6-10</sup>

In the Israeli Defense Force, preventive actions such as questioning soldiers about their health status before participating in strenuous activity, a strict regime of work-rest cycles, hydration guidelines, and exercise restrictions according to heat load are applied. However, even when complying with the required preventive guidelines, EHS still can appear

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TABLE I. EHS Risk Factors

|   |
|---|
| Inherent Personal Factors   |
| Dehydration   |
| Age (>40)   |
| Nutritional State   |
| Sleep Deprivation   |
| Low Fitness   |
| Obesity   |
| Heat Acclimatization  |
| Acute Illness (Flue-like, Fever, Gastrointestinal)  |
| Chronic Disease (Mostly Neurologic, Dermatologic, Endocrinologic)                         |
| Medications and Substance Abuse (Medications that Interfere with Heat Loss or Production) |
| Personal Motivation   |
| Environmental Factors   |
| High Environmental Temperature  |
| High Humidity   |
| Worm Clothes  |
| Activity-Related Factors  |
| Rest/Work Cycles  |
| Intensity of Activity   |
| Peer Pressure and Superior Level Requirements   |

sporadically in previously healthy persons without any known risk factors.<sup>11</sup> Thus, emphasis should be given not only to prevention but also to early recognition and rapid and aggressive treatment.

The presentation of EHS is usually acute and includes neurological symptoms with elevated body temperature.<sup>12</sup> Moreover, about 20% of patients have prodromal symptoms.<sup>5</sup> Failure to recognize these symptoms and begin proper treatment might lead to further damage that can cause death. Central nervous system (CNS) involvement is present in all EHS cases, and therefore, is the most important prediagnostic symptom.<sup>12</sup> CNS symptoms may include loss of consciousness, stupor, delirium, irritability, confusion, agitation, seizures, irrational behavior, amongst others.<sup>11</sup>

Sinus tachycardia is present because of increased metabolic rate and changes in circulation corresponding with peripheral vasodilatation.<sup>13</sup> Cardiac output is usually low, probably as a result of a combination between direct effect of heat on the heart, on the pulmonary vascular resistance, and on the peripheral vasodilatation.<sup>14</sup> ECG might show different abnormalities in EHS patients, such as conduction defects and ST-T segment changes.<sup>15</sup>

The current case presented with prodromal symptoms of heat stroke, mostly CNS, that were misdiagnosed. The patient was also tachycardic, and the physician failed to relate this to a possible high body temperature following intensive exercise in heavy heat load. During hospitalization, the patient exhibited more symptoms, signs, and laboratory findings that are classically described in EHS patients, including renal, muscle, and liver damage, peaking from 18 to 36 hours from injury, electrolyte imbalance, and coagulopathy. The patient did not develop more severe complications (e.g., acute respiratory distress syndrome, disseminated intravascular coagulopathy,

or any permanent damage), probably because of prompt diagnosis and aggressive treatment in the ER.

Data collected regarding EHS cases indicate that prompt body temperature reduction, seizure control, early rehydration, and rapid hospital evacuation result in more than a 95% survival rate.<sup>5,12,16</sup> In the field, the patient should be moved to a shaded area, undressed, cooled by spraying using large amounts of water, and transported to a nearby hospital.<sup>6,11</sup> There are many cooling methods (e.g., ice packs, ice water baths, alcohol sponge, air conditioning),<sup>6,14,17</sup> but the most practical and effective method for an EHS patient in the field is using generous amounts of tap water, which can reach a cooling rate of 0.1 to 0.2°C per minute.<sup>17</sup> To confirm the diagnosis of EHS, rectal temperature should be taken as soon as possible before cooling, but it should not delay the treatment if, for example, a rectal thermometer is unavailable. A venous catheter should be placed as a means for treating potential seizures by diazepam and for hydrating the patient.<sup>11</sup>

## CONCLUSIONS

EHS is a syndrome caused by excessive elevation of body temperature, typically presenting with neurologic symptoms and high body core temperature during or after strenuous physical activity. It usually occurs during high heat load, but can also occur in cool weather.<sup>18</sup> Unless diagnosed and treated promptly, EHS may lead to serious injury, disability, and even death. The current patient had the signs of EHS with a short prodromal period, but was not diagnosed correctly by the field physician who mostly ignored both the CNS signs and the fact that the soldier collapsed during exercise in the heat. Later on, the patient manifested common complications of EHS and 7 weeks after the injury was diagnosed as heat intolerant. Three months later the patient recovered. His HTT results were normal, and he was allowed to go back to active military duty. Long recovery after heat stroke in this case probably might have been prevented with proper diagnosis and early treatment. Noteworthy, a misdiagnosis of heat stroke can occur as a result of disregarding major symptoms and anamnesis even by a trained military physician. It is also imperative to rule out EHS in any case of collapsing during exercise.

## REFERENCES

1. Moran DS, Heled Y, Still L, Laor A, Shapiro Y: Assessment of heat tolerance for post exertional heat stroke individuals. *Med Sci Monit* 2004; 10: 252-7.
2. Shibolet S, Coll R, Gilat T, Sohar E: Heat stroke: its clinical picture and mechanism in 36 cases. *Q J Med* 1967; 36: 525-47.
3. Shapiro Y, Rosenthal T, Sohar E: Experimental heat-stroke: a model in dogs. *Arch. Intern Med* 1973; 131: 688-91.
4. Kuan-Che L, Tzong-Luen W: Heat stroke. *Ann Disaster Med* 2004; 2: 97-109.
5. Epstein Y, Sohar E, Shapiro Y: Exertional heatstroke: a preventable condition. *Isr J Med Sci* 1995; 31: 454-62.
6. Armstrong LE, Casa DJ, Millard-Stafford M, Moran DS, Pyne WS, Roberts WO: American College of Sports Medicine position stand.

Case Report

- Exertional heat illness during training and competition. *Med Sci Sports Exerc* 2007; 39: 556-72.
7. Shvartz E, Shapiro Y, Magazanik A, et al: Heat acclimation, physical fitness, and responses to exercise in temperate and hot environments. *J Appl Physiol* 1977; 43: 678-83.
  8. Moran DS, Gaffin SL: Pathophysiology of heat-related illnesses. In: *Wilderness Medicine*, Ed 5, pp 228-68. Edited by Auerbach PS. Philadelphia, MOSBY Elsevier, 2007.
  9. Epstein Y: Heat intolerance: predisposing factor or residual injury? *Med Sci Sports Exerc* 1990; 22: 29-35.
  10. Armstrong LE, De Luca JP, Hubbard RW: Time course of recovery and heat acclimation ability of prior exertional heatstroke patients. *Med Sci Sports Exerc* 1990; 22: 36-48.
  11. Shapiro Y, Seidman DS: Field and clinical observations of exertional heat stroke patients. *Med Sci Sports Exerc* 1990; 22: 6-14.
  12. Bouchama A, Knochel JP: Heat stroke. *N Engl J Med* 2002; 346: 1978-88.
  13. Khogali M: Heat stroke: an overview. In: *Heat Stroke and Temperature Regulation*, pp.1-12. Edited by Khogali M, Hales JRS. Sydney, Academic Press, 1983.
  14. Clowes GHA, O'Donnel TF: Heat stroke. *N Engl J Med* 1974; 291: 564-7.
  15. Akhtar MJ, al-Nozha M, al-Harhi S, Nouh MS: Electrocardiographic abnormalities in patients with heat stroke. *Chest* 1993; 104: 411-4.
  16. Heled Y, Rav-Acha M, Shani Y, Epstein Y, Moran DS: The "golden hour" for heatstroke treatment. *Mil Med* 2004; 169: 184-6.
  17. Smith JE: Cooling methods used in the treatment of exertional heat illness. *Br J Sports Med* 2005; 39: 503-7.
  18. Roberts WO: Exertional heat stroke during a cool weather marathon: a case study. *Med Sci Sports Exerc* 2006; 38: 1197-202.
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# heat stress

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**H**eat stress is a combination of direct environmental variables (mainly temperature and humidity), work rate and clothing requirements. These factors combine with indirect acclimatization and physical conditions to increase body temperature and cardiovascular demands. Acclimatization to heat involves a series of physiological and psychological adjustments that occur in an individual during the first week of exposure to hot environmental conditions. Extra caution must be taken when workers who are not acclimated or physically fit must be exposed to heat stress conditions. The greater the heat stress is on these workers, the greater the resulting physiological strain. Heat stress can diminish performance and adversely affect health and safety. Most heat-related injuries can be avoided if people are aware of their environment and can recognize heat stress symptoms.

The three types of heat-induced illnesses include heat strain, heat exhaustion, and heatstroke. Transition from one to the next can be very evident, hardly noticeable, or not evident at all.

Heat strain is when the body temperature is between 99.5 and 100 degrees Fahrenheit. It reduces performance, dexterity, coordination, and alertness. Incidence and severity will vary among people.

Heat exhaustion is when the body temperature is between 101 and 104 degrees Fahrenheit.

It may cause fatigue, nausea/vomiting, cramps, rapid shallow breathing, and fainting. The skin is pale, cool, clammy, and moist with profuse sweating, and the pulse rate is weak. In its most serious form, heat exhaustion leads to prostration and can cause serious injuries.

Heatstroke is when the body temperature is greater than 104 degrees Fahrenheit. It is the most serious heat-induced illness because of its potential to be life threatening or result in irreversible damage. Heatstroke results from the body losing its ability to lower its temperature. The heatstroke victim is often manic, disoriented, confused, delirious or unconscious. The victim's skin can be hot and dry because sweating has ceased. If treatment is not immediate, the victim's condition can deteriorate to convulsions, brain damage,

**Heat stress can diminish performance and adversely affect health and safety**

age, and eventual death. Immediate emergency care and hospitalization are essential if signs of heatstroke develop. Cool down by any method available and transport to the nearest medical facility for treatment.

Assessment of heat stress can be conducted by measuring the physical factors of the environment. The commonly used area monitoring measurement is Wet Bulb Globe Temperature (WBGT). This index relates atmospheric effects to heat stress in outdoor and harsh industrial environments.

## Physics of Heat

According to thermodynamics, and a great deal of paraphrasing, heat is transferred in three ways: radiation, convection, and conduction.

**Radiation** — This refers to heat that is exchanged from distant objects (like solar radiant heat or a heater in a room). Certain objects, depending on color and composition, retain and continue to radiate heat (like asphalt, rocks, or dark clothing).

**Convection** — This refers to the relative movement of air that increases heat exchange. This method is used in convection ovens to cook food efficiently and evenly. Air movement when the temperature exceeds body temperature may increase heat stress. Imagine again your convection oven. Fans cannot cool a person when the temperature exceeds 90 degrees Fahrenheit and humidity is greater than 35 percent. Fans have actually caused heat stress when the temperature is above 100 degrees Fahrenheit. During outdoor activity, certain types of clothing limit the relative wind across the skin, restrict evaporation of sweat, and add a layer of trapped air as insulation.

**Conduction** — This refers to the direct contact with objects allowing heat exchange (i.e., touching a hot iron). Good thermal conductors transfer heat quickly. Sit on a hot metal playground slide wearing shorts and you will clearly understand conduction. Humidity is an environmental factor that makes it "feel hotter." As the relative humidity increases, evaporation is inhibited, reducing the effectiveness of the body's natu-

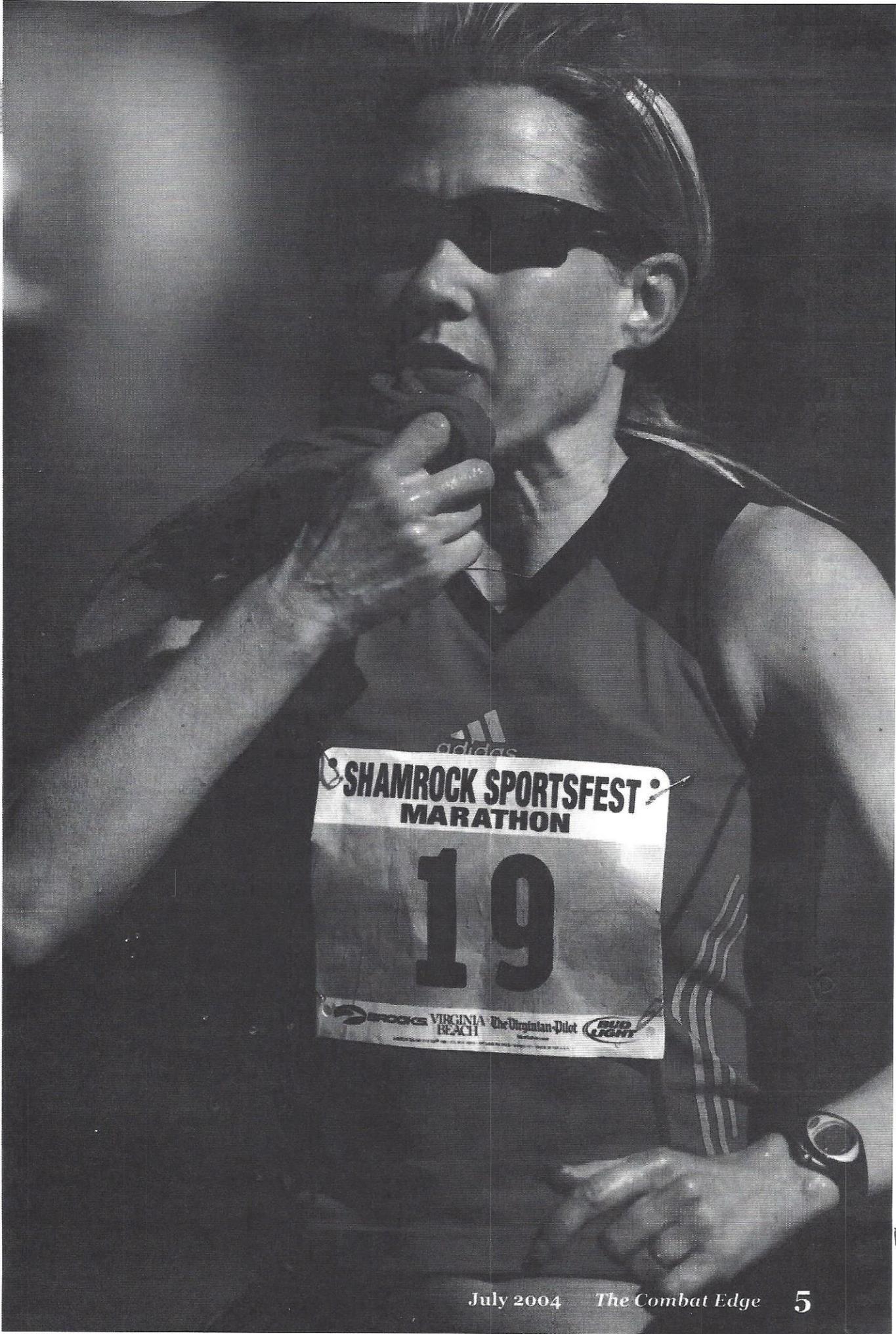


Photo by TSgt Ben Blaker

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ral response to heat. This makes it feel much hotter than the actual temperature reflects. Meteorologically speaking, this is the heat index. The heat index, similar to windchill in the winter, establishes an apparent temperature by comparing either temperature/relative humidity (see heat index chart) or temperature/dew point.

As physical activity increases, so does the amount of muscular heat produced in the body core. The more you move and exert yourself, the more heat your

muscles produce. This is why one uncontrollably shivers during very cold temperatures, heat exhaustion, or even heatstroke, as the body can no longer maintain a safe core temperature.

### **Physiological Response to Heat**

Skin plays a central role in maintaining a constant body temperature of 98.6 degrees Fahrenheit (37 C) in two ways. First, capillaries in the skin exchange heat with the environment. In hot weather, these

capillaries dilate (cutaneous vasodilation), allowing increased blood flow and heat exchange along the surface of the skin through both conduction and convection. Besides sunburn, this is the reason skin appears red during exercise or hot weather. Second, the skin aids in cooling the core temperature through evaporation. When body temperature increases above 98.6 degrees Fahrenheit, the body actively secretes sweat, containing water and salt from sweat glands in the skin, increasing evaporation and heat loss. Similarly, the exchange across the capillaries of the lungs and the release of water vapor through respiration regulate body temperature.

Additionally, the body reacts in several other ways to decrease body core temperature. The body decreases metabolic rate, thereby lowering metabolic heat production in the body core. In hot weather, behavioral reactions decrease internal temperatures. For example, people naturally become lethargic and tend to rest or lie down. This decreases heat production and increases heat loss to regulate body core temperature.

On a normal day, the body loses approximately 2 liters or a 1/2 gallon of water as imperceptible evaporation from the skin or during respiration. During hot weather and during strenuous physical activity, perspiration increases the rate of water loss. As the body loses water, its ability to regulate temperature is greatly affected. On very hot days and during exercise, by the time you recognize the feeling of thirst it may already be too late! You may not be able to overcome your hydration deficit with continued exposure or physical activity. As one becomes more dehydrated,

there is not enough water volume in the body for adequate circulation and thermoregulation. Prolonged dehydration can lead to heat exhaustion or even heat-stroke, as the body can no longer maintain a safe core temperature.

### Prevention

There are several things you can do to prevent heat stress injuries.

**Stay hydrated.** Drink plenty of fluids 30 to 45 minutes before exercise and then a cupful every 10 to 15 minutes during exercise. Drink non-alcoholic beverages. Water or sports replacement drinks are the best way to replenish your fluid deficit. Alcohol and caffeine will promote dehydration.

**Wear light colored, loose fitting clothing.** Moisture wicking

fabrics will help evaporation and keep you cooler than heavier fabrics that retain heat. Also, wearing a hat and sunglasses will prevent sunburn, making you feel much more comfortable in the outdoors.

**Allow yourself time to acclimate to the heat.** Gradually build your heat tolerance in warmer weather. It may take several weeks before you can perform moderate to heavy tasks in higher temperatures. A heat-acclimated person may perspire more than twice as much as an unacclimated person, allowing them to better regulate body temperature.

Physical conditioning is very important as to how your body reacts to heat. Individuals with a higher oxygen uptake are more

tolerant of heat than those with lower fitness levels. Also, fat is a great insulator. Extremely obese people are six times more likely to suffer heat stroke than thin people.

Finally, avoid the heat whenever possible. Plan your activities to avoid the hottest part of the day or stay in the shade. Limit outdoor activities during humid days (high heat index).

Understanding the physics and physiology of heat is vitally important when it comes to safely enjoying any summertime activity. Be familiar with the symptoms of heat stress disorders and know the proper first aid — for yourself and those around you. Allow time to acclimate to the heat and use proper prevention measures. Now get outside and stay cool. ▶

# Heat Index Table

| Relative Humidity | Air Temperature (F) |    |    |     |     |     |     |     |     |     |     |
|-------------------|---------------------|----|----|-----|-----|-----|-----|-----|-----|-----|-----|
|                   | 70                  | 75 | 80 | 85  | 90  | 95  | 100 | 105 | 110 | 115 | 120 |
| 30                | 67                  | 73 | 78 | 84  | 90  | 96  | 104 | 113 | 123 | 135 | 148 |
| 35                | 67                  | 73 | 79 | 85  | 91  | 98  | 107 | 118 | 130 | 143 |     |
| 40                | 68                  | 74 | 79 | 86  | 93  | 101 | 110 | 123 | 137 | 151 |     |
| 45                | 68                  | 74 | 80 | 87  | 95  | 104 | 115 | 129 | 143 |     |     |
| 50                | 69                  | 75 | 81 | 88  | 96  | 107 | 120 | 135 | 150 |     |     |
| 55                | 69                  | 75 | 81 | 89  | 98  | 110 | 126 | 142 |     |     |     |
| 60                | 70                  | 76 | 82 | 90  | 100 | 114 | 132 | 149 |     |     |     |
| 65                | 70                  | 76 | 83 | 91  | 102 | 119 | 138 |     |     |     |     |
| 70                | 70                  | 77 | 85 | 93  | 106 | 124 | 144 |     |     |     |     |
| 75                | 70                  | 77 | 86 | 95  | 109 | 130 |     |     |     |     |     |
| 80                | 71                  | 78 | 86 | 97  | 113 | 136 |     |     |     |     |     |
| 85                | 71                  | 78 | 87 | 99  | 117 |     |     |     |     |     |     |
| 90                | 71                  | 79 | 88 | 102 | 122 |     |     |     |     |     |     |
| 95                | 71                  | 79 | 89 | 105 |     |     |     |     |     |     |     |
| 100               | 72                  | 80 | 91 | 108 |     |     |     |     |     |     |     |

### HEAT INDEX

**80°F-90°F**

**90°- 105°F**

**105°F - 130°F**

**130°F or greater**

### POSSIBLE HEAT DISORDER

**Fatigue possible with prolonged exposure and physical activity**

**Sunstroke, heat cramps and heat exhaustion possible**

**Sunstroke, heat cramps, and heat exhaustion likely, and heat stroke possible**

**Heat stroke highly likely with continued exposure**

\* Heat and humidity affect everybody differently. Several assumptions are used to calculate the Heat Index. The Heat Index assumes that the body is 5 feet 7 inches tall, 147 pounds, caucasian, body temperature at 98.6 degrees, clothed in long trousers and a short-sleeved shirt, in shade, walking at a speed of 3.1 miles per hour, in a breeze of 6 miles per hour, not dripping sweat.

Note: If any of these factors change, e.g., more exertion, more clothing, and/or more weight, the Heat Index will change for that individual. Exposure to full sunshine can increase Heat Index values by up to 15 degrees Fahrenheit.

## The "Golden Hour" for Heatstroke Treatment

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Exertional heatstroke is a life-threatening event. It occurs mainly among the young healthy populations of athletes and soldiers. The severity of exertional heatstroke is directly correlated to the area under the temperature duration curve. Therefore, rapid cooling in the field has an enormous effect on prognosis. Four cases of exertional heatstroke are presented which differ in their outcome. We argue that there is a "window time period" within which simple and effective cooling techniques can determine prognosis.

### Introduction

Heatstroke is one of the most serious conditions associated with elevated body temperature.<sup>1</sup> It occurs when metabolic and environmental accumulated heat exceeds the body's ability to dissipate it. The elevated body core temperature becomes a noxious agent, causing damage to the body's tissues and resulting in a characteristic multiorgan clinical and pathological syndrome, which is occasionally fatal.<sup>2,3</sup>

Heatstroke may appear in one of two forms: classical heatstroke or exertional heatstroke (EHS). The former affects mainly the elderly during severe heat waves.<sup>4,5</sup> The latter is a sporadic event occurring among the young healthy population of soldiers, athletes, miners, etc., and is associated with heavy exertions, not necessarily held under heavy heat loads.<sup>4,6</sup> Complications of EHS may include hepatic failure, renal failure, disseminated intravascular coagulation, rhabdomyolysis, and the adult respiratory distress syndrome.<sup>3,7-9</sup>

The severity of EHS can be affected by the duration of unconsciousness (less than 1 hour in mild cases and 3 to 24 hours in severe cases) and by the levels of hepatic and coagulation enzyme disturbances.<sup>2,7,8</sup> The severity of EHS has been shown to be directly and closely correlated with the area under the temperature-duration curve.<sup>10</sup> Thus, decreasing the length of time at which the body remains above a critical temperature should have a crucial influence on the EHS victim's outcome and prognosis.<sup>5,10</sup>

In this article, we present four cases of EHS that differ in their severity and outcome, which we argue was mainly attributed to the different time intervals until proper treatment was initiated. These cases demonstrate the importance of the "golden hour" as a lifesaving time interval in the case of EHS.

### Case Reports

#### Case 1

A 26-year-old previously healthy man participated in a pre-draft military selection program, which took place during mod-

erate heat load (ambient temperature ( $T_a$ ) = 24°C (45.3°F), relative humidity (RH) = 60%). The exercise regimen consisted of short and long running distances with various back loads and other various interval trainings. After 2 hours of high-intensity exercises, the trainee collapsed. His rectal temperature ( $T_{re}$ ), measured on site with a clinical thermometer, was above 42.5°C (55.6°F) (the end of the thermometer's scale). Cooling treatment by splashing copious amounts of water on his body was immediately initiated. In the emergency room, 45 minutes later, the patient was psychotic, aggressive, and with a  $T_{re}$  of 40.0°C (54.2°F). Within 1 hour of treatment consisting of continued cooling, intravenous fluids, and intramuscular haloperidol,  $T_{re}$  decreased to 37.5°C (52.8°F). One hour later, the soldier recovered to full consciousness. He was then hospitalized for 3 days, during which time he was free from complaints. Laboratory evidence revealed muscular damage with creatine phosphokinase activity peaking at 6,010 U/L 24 hours from the collapse and an increase in liver enzymes: alanine aminotransferase, 97 U/L; aspartate aminotransferase, 228 U/L; lactate dehydrogenase, 392 U/L; prothrombin time, 74% (normal range, 70%–120%); and partial thromboplastin time, 28 seconds (normal range, 28–40 seconds). There was no other evidence of liver dysfunction. All laboratory results returned to normal values within 1 week after the collapse. A heat tolerance test was performed according to Shapiro et al.<sup>11</sup> after 8 weeks and demonstrated normal physiological response to exercise heat stress.

#### Case 2

An 18-year-old soldier collapsed at the end of a 12-km march (2.5-hour duration) held under moderate heat load ( $T_a$  = 26°C (46.4°F), RH = 50%). Rectal temperature measured upon collapse was 41.0°C (54.8°F). The soldier was immediately cooled by extensive amounts of tap water and cold intravenous infusion. On his arrival at the emergency ward 1 hour later, the soldier was fully conscious with  $T_{re}$  = 38.0°C (53.1°F). Laboratory examination the following day revealed muscle damage with creatine phosphokinase activity levels peaking at 44,000 and hepatic elevated enzymes: alanine aminotransferase, 250 U/L; aspartate aminotransferase, 600 U/L; and bilirubin, 1.2 mg/dL. There was no evidence of renal or coagulation dysfunction. The soldier was hospitalized for 5 days with no complaints. Eight days later, all laboratory results returned to normal values. A heat tolerance test,<sup>11</sup> performed 4 weeks after the EHS occasion demonstrated a normal physiological response to exercise in a hot climate.

#### Case 3

An 18-year-old military recruit participated in a 5-km (1-hour) night march, carried out under moderate heat load ( $T_a$  = 26°C (46.4°F), RH = 78%). At the end of the march, the soldier collapsed. A few minutes later, at the base clinic, the patient was

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delirious with alternating aggressive behavior and vomited several times. Hyperventilation, aggressive reaction, and history of a previously healthy subject participating in a short march led the physician in charge to misdiagnose the condition as conversion reaction and, therefore, body temperature was not measured. After 3 hours, convulsions accompanied by dark vomiting appeared, and the patient was evacuated to a hospital. On admission to the emergency room 4 hours after the collapse, the patient was comatose, in shock (systolic blood pressure, 60), and had a rectal temperature of 39.6°C (54.0°F), which was the first measurement. Laboratory examination revealed: metabolic acidosis (pH 7.2; bicarbonate, 15); creatinine, 4.4 mg/dL; aspartate aminotransferase, 550 U/L; prothrombin time, 10% of normal; and partial thromboplastin time, 85 seconds. Despite intensive treatment including infusion of 12 L of crystalloid fluid, albumin, blood, fresh frozen plasma, dopamine, and steroids (for blood pressure maintenance), the patient died 24 hours later. Blood cultures taken on admission were sterile. Heatstroke diagnosis was confirmed by autopsy.

#### Case 4

A 20-year-old infantry soldier participated in a competitive 5-km run with full battle gear during moderate heat load ( $T_a = 28^\circ\text{C}$  (47.7°F), RH = 60%). The run took approximately 25 minutes to complete, after which the soldier collapsed. No cooling measures were taken, and he was evacuated to a nearby infirmary. Upon arrival 15 minutes later, he was unconscious with  $T_{re}$  of 40.5°C (54.5°F). The only attempt to cool him was the placing of several ice cubes on his chest, and he was referred to a hospital. The patient arrived to the hospital approximately 60 minutes after the collapse. On examination at the emergency room, he was still unconscious, and  $T_{re}$  was 40.0°C (54.2°F). He was intubated and given intravenous fluids and 1 g of paracetamol by suspension. The patient was then admitted to the intensive care unit. He arrived at the intensive care unit 2 hours after his collapse, while his  $T_{re}$  was still 39.6°C (54.0°F). Cooling was initiated by repeated cold water gastric lavage. Three hours after his collapse, the patient's  $T_{re}$  was 38.5°C (53.4°F), and shortly afterward he was extubated. The patient was given an additional 2 g of paracetamol during the first day of hospitalization. On the following day, the soldier's condition deteriorated with evidence of acute hepatic failure, disseminated intravascular coagulation, and adult respiratory distress syndrome. Despite intensive treatment (preparation for liver transplantation was initiated), the patient died of multiple organ failure on the fifth day after his collapse. Postmortem examination confirmed the diagnosis of EHS.

#### Discussion

EHS is a threat to all of those who engage in vigorous physical exertion. It is of particular concern in military situations where the combination of high-intensity exercise coupled with overmotivation and peer pressure may prove to be detrimental. The damage inflicted by EHS is determined by the degree of hyperthermia and its duration and is a function of the temperature-duration area above a critical temperature.<sup>10,12,13</sup> Cooling is a

lifesaving treatment for EHS victims. It should, therefore, be initiated immediately upon collapse and only minimally delayed for vital resuscitation measures.<sup>8</sup>

In the present study, four cases of EHS that occurred after relatively short periods of exercise are presented. In cases 1 and 2, effective cooling and using large quantities of tap water were applied shortly after the collapse. Both cases enjoyed favorable prognosis with complete recovery after hospitalization of less than a week. Despite the high initial rectal temperatures (42.5°C (55.6°F) and 41.0°C (54.7°F), respectively), the cases were summarized as mild, as evidenced by the relatively short period of unconsciousness, mild to moderate rhabdomyolysis, and hepatorenal dysfunction. The mild course and the good prognosis were in all probability a direct consequence of the rapid cooling rate of 2.5 to 3.0°C (33.4–33.6°F) during the first hour after collapse.

In cases 3 and 4, cooling treatment was delayed. In case 3 the primary physician misdiagnosed the patient as having a conversion reaction. Thus, body temperature was not even measured, a fact that delayed treatment and evacuation. In case 4, EHS was diagnosed by the primary physician at the site of collapse and also in the emergency room. However, this resulted in only futile actions being taken. Efficient cooling was initiated only 3 hours after the collapse when the patient was referred to the intensive care unit. Furthermore, the use of paracetamol in this case was particularly unjust and might even have been harmful.

Various cooling methods, such as alcohol sponge, ice packs, cold or ice water immersion,<sup>14,15</sup> or evaporative cooling using air conditioners, powerful fans,<sup>14,16,17</sup> or sophisticated "body cooling unit" equipment<sup>18</sup> have been reviewed in the literature. Nevertheless, the necessity to reduce body temperature as quickly as possible requires simple and effective methods that can be applied at the site of collapse. It has been found that the most practical and efficient cooling methods in the field consist of spraying large quantities of tap water (15–16°C (40.3–40.9°F)) on the skin, providing shade, and finding some means of blowing air on the patient.<sup>9,13,15</sup> Tap water is readily available in a field scenario, does not require medical expertise, and can be applied by military commanders or organizers of sports events as well. It does not require sophisticated logistic arrangements or equipment, which are required for other cooling techniques. Cooling by tap water, as opposed to ice water, has a physiological rationale, because it eliminates the hazard of cold-induced vasoconstriction and heat-producing shivering, which reduce cooling effectiveness.<sup>3,13,15</sup> The physiological advantage of rapid cooling with tap water was endorsed by the American College of Sports Medicine. The college adopted this method as its "method of choice" and incorporated it in their position stand.<sup>19</sup>

Antipyretics have no role in the treatment of EHS, as they only serve to readjust the body's temperature set point in cases of disease. In EHS, the body temperature's set point is not elevated but rather overwhelmed.<sup>13,16</sup> Moreover, paracetamol may be detrimental to the development of fulminant hepatitis in EHS patients because of previous heat-induced hepatic damage. The misdiagnosis in case 3 and the improper futile cooling treatment in case 4 caused a delay in efficient cooling, which only occurred 3 to 4 hours after the collapse. The result of this delayed cooling most probably played a major role in the deaths of the patients.

## Summary and Conclusions

All four cases presented herein deal with young, healthy, physically fit subjects in whom EHS occurred after a short duration of strenuous activity held under moderate heat conditions. Thus, all of these cases are similar EHS cases in which the subjects suffered for only a few hours the noxious effect of the heat. Nevertheless, the outcome of the first two cases was totally different compared with the other two cases. In the first two cases, the length of time that elapsed from collapse to the initiation of cooling differed from the last two cases. The first cases were rapidly cooled soon after the collapse by simple available means of tap water, whereas in the other two cases efficient cooling was delayed for more than 3 hours. This was probably detrimental for prognosis. We can conclude from these cases that there is a limited "window time period" within which effective cooling can influence prognosis. Delaying cooling will result in poor prognosis or even death. The term "golden hour," used in trauma to describe the period until the initiation of treatment, is also relevant for the cooling of heatstroke patients. Initiation of efficient cooling immediately after the EHS event (collapse), beginning at the site of the event, is of crucial importance and cannot be emphasized enough. A delay in the efficient cooling even at the hospital level may have a catastrophic implication on prognosis.

Using large quantities of tap water at the scenario site and during the evacuation has proven to be an effective cooling method, with a rate of 2.5 to 3.0°C/h (33.4–33.6°F/h) reduction in body temperature. Postponing the cooling treatment until more sophisticated equipment is available may be harmful or even life-threatening.

The use of antipyretics in the treatment of heatstroke is contraindicated because there is no change in the hypothalamic temperature set point.<sup>13,16</sup> However, recent data have shown pyrogenic cytokines to be involved in heatstroke pathogenesis,<sup>3,20</sup> thus, favoring their use. Case 4 is a "strong" clinical example of the potential hazard that exists in the use of antipyretics (e.g., paracetamol) to cool heatstroke victims. Therefore, our position is against their use in EHS victims.

## References

1. World Health Organization: Manual of Internal Statistical Classification of Diseases, Injuries and Causes of Death, 9th Revision. Geneva, WHO, 1977.
2. Shibolet S, Coll R, Gilat T, Sohar E: Heatstroke: its clinical picture and mechanism in 36 cases. *Q J Med* 1967; 36: 525–47.
3. Bouchama A, Knochel JP: Heat stroke. *N Engl J Med* 2002; 346: 1978–88.
4. Khogali M: Heatstroke: an overview. In *Heatstroke and Temperature Regulation*, pp 1–12. Edited by Khogali M, Hales JRS. Sydney, Academic Press, 1983.
5. Hart GR, Anderson RJ, Crumpler CP, Shulkin A, Reed G, Knochel JP: Epidemic classical heatstroke: clinical characteristics and course of 28 patients. *Medicine* 1982; 61: 189–97.
6. Epstein Y, Moran DS, Shapiro Y, Sohar E, Shemer J: Exertional heat stroke: a case series. *Med Sci Sports Exerc* 1999; 31: 224–8.
7. Shibolet S, Lancaster MV, Danon Y: Heat stroke: a review. *Aviat Space Environ Med* 1976; 47: 280–301.
8. Shapiro Y, Seidman DS: Field and clinical observations of exertional heat stroke patients. *Med Sci Sports Exerc* 1990; 22: 6–14.
9. Epstein Y, Sohar E, Shapiro Y: Exertional heat stroke: a preventable condition. *Isr J Med Sci* 1995; 31: 454–62.
10. Shapiro Y, Rosenthal T, Sohar E: Experimental heat-stroke: a model in dogs. *Arch Int Med* 1973; 131: 688–91.
11. Shapiro Y, Magazanik A, Udassin R, Ben-Baruch G, Shvartz E, Shoenfeld Y: Heat intolerance in former heat stroke patients. *Ann Int Med* 1979; 90: 913–6.
12. Epstein Y, Shani Y, Moran DS, Shapiro Y: Exertional heatstroke: the prevention of a medical emergency. *J Basic Clin Physiol Pharmacol* 2000; 11: 395–401.
13. Epstein Y: Exertional heat stroke: lessons we tend to forget. *Am J Med Sports* 2000; 2: 143–52.
14. Wyndham CH, Strydom NB, Cooke HM, Maritz JS, Morrisson JS, Ward JS: Methods of cooling subjects with hyperpyrexia. *J Appl Physiol* 1959; 14: 771–6.
15. Magazanik A, Epstein Y, Udassin R, Shapiro Y, Sohar E: Tap water, an efficient method for cooling heat stroke victims: a model in dogs. *Aviat Space Environ Med* 1980; 51: 864–7.
16. Tek D, Olshaker JS: Heat illness. *Emerg Med Clin North Am* 1992; 2: 299–310.
17. Costrini A: Emergency treatment of exertional heat stroke and comparison of whole body cooling techniques. *Med Sci Sports Exerc* 1990; 22: 15–8.
18. Weiner JS, Khogali M: A physiological body cooling unit for treatment of heatstroke. *Lancet* 1980; 1: 507–9.
19. American College of Sports Medicine: Position stand on heat and cold illness during distance running. *Med Sci Sports Exerc* 1996; 28: i-x.
20. Lin MT, Liu HH, Yang PL: Involvement of interleukin-1 receptor, mechanisms in development of arterial hypotension in rat heatstroke. *Am J Physiol* 1997; 273: 2072–7.



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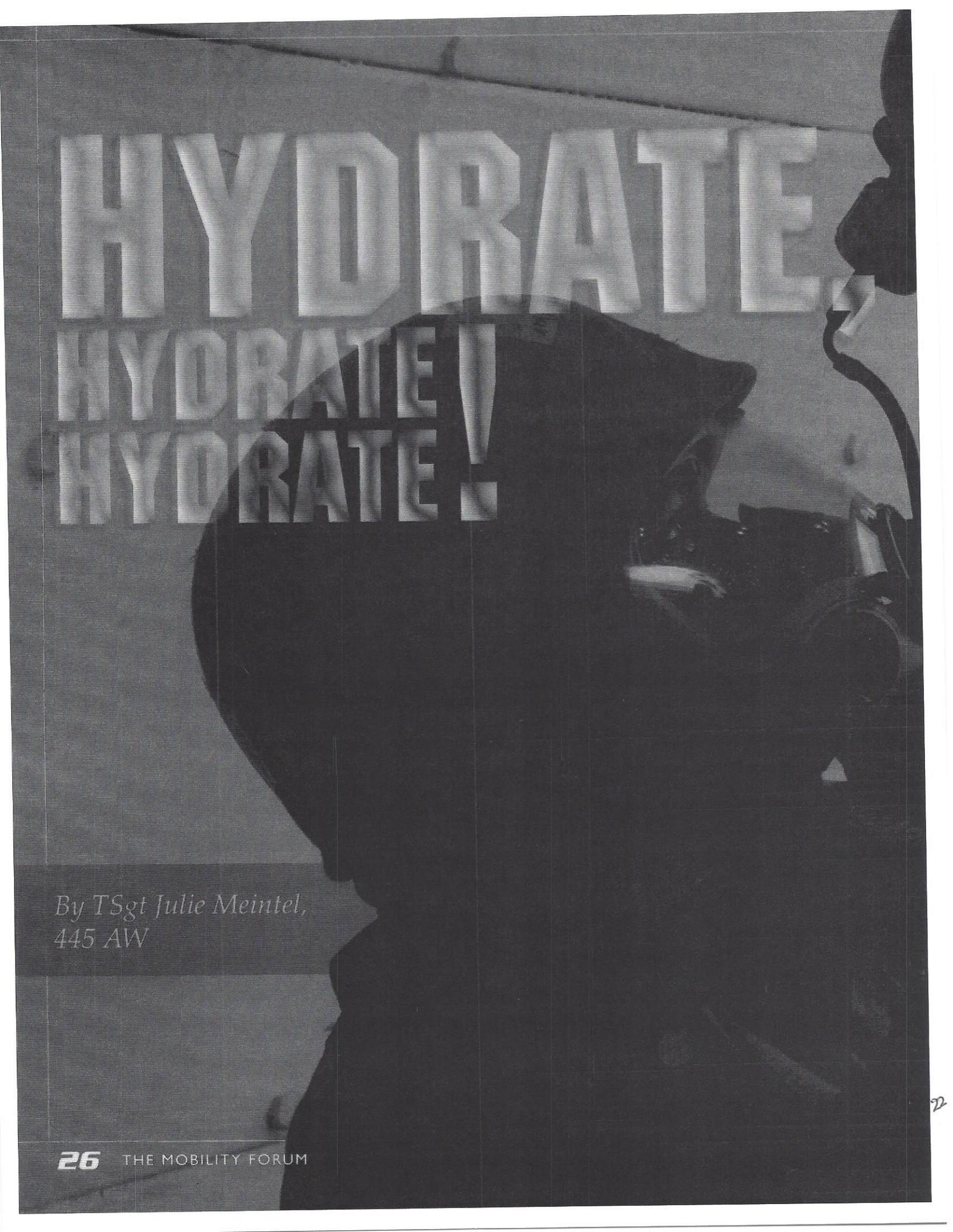
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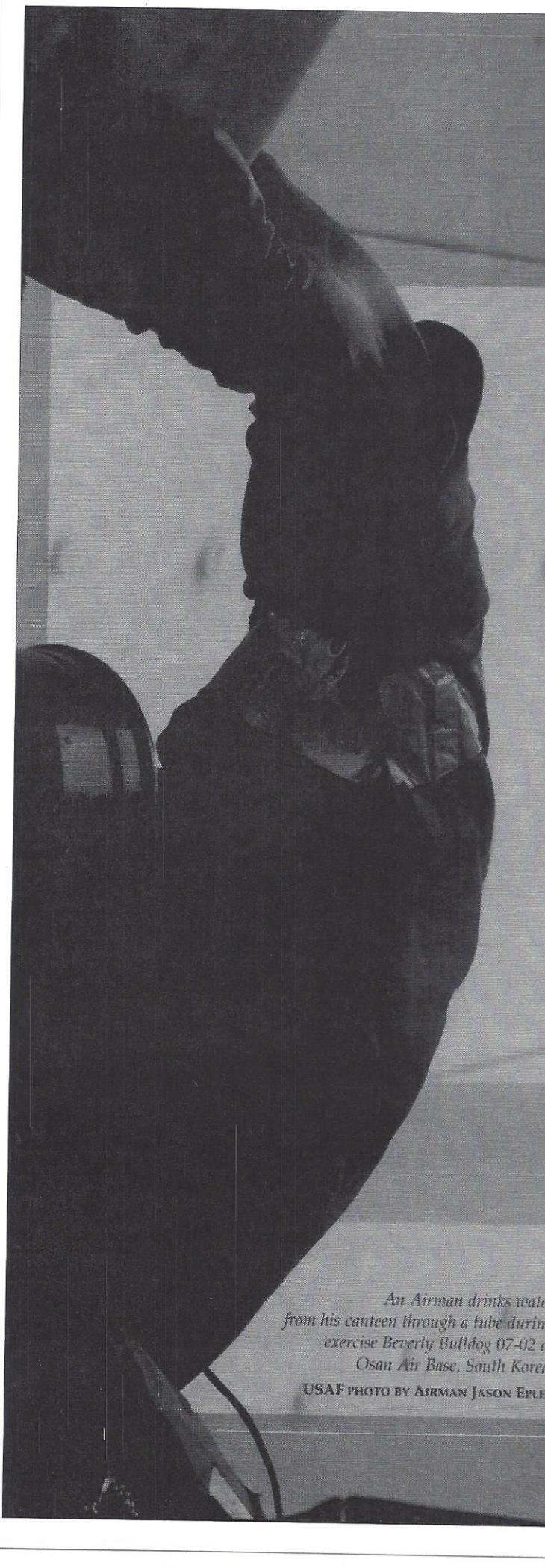
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HYDRATE  
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*By TSgt Julie Meintel,  
445 AW*



# Y

ou're driving along the streets of Baghdad, on patrol with your team. It's 115 degrees out. You notice one of the guys with you seems disoriented, and can't seem to catch his breath. You get a little closer and see that he is very pale and can't seem to focus his eyes on you. When you reach out to help him, he feels like he is on fire. You open his canteen for him, and that's when you notice it's still full...he hasn't touched it.

Heat stress can happen because we're doing too much in a too-hot climate, whether it's patrolling a flight line in scorching desert temperatures or running outside during the hottest part of the day. Heat stress takes several different forms of varying severity and in a rare, worst-case scenario, it can be fatal.

Something to consider: in Iraq, temperatures can easily reach well over 100 degrees in the summer. How easy would it be, to be out on patrol, driving a supply truck, or loading an airplane, and be quickly overwhelmed by the heat? Heat illness is insidious: you may not realize what is happening until you are already in the throes of a heat injury.

The least severe heat injury is a condition called heat cramps, which can manifest themselves in the form of muscle spasms, or twitching in the arms, legs or possibly the abdomen. Secondly, heat syncope (brief loss of consciousness), also known as fainting, shows up with symptoms like general weakness and fatigue, low blood pressure, occasionally blurred vision, pallor or very pale skin, and elevated skin/core body temperature.

Moving on to heat exhaustion due to water depletion, we see reduced sweating, dry tongue or dry mouth, elevated skin/core body temperature, weakness and loss of coordination with jerky movements. Heat exhaustion due to salt depletion is a little different. Symptoms include headache and dizziness, fatigue, nausea, possibly vomiting and/or diarrhea, syncope (brief loss of consciousness), and muscle cramps. This condition comes on gradually and can take up to 3-5 days to fully develop and manifest.

*An Airman drinks water from his canteen through a tube during exercise Beverly Bulldog 07-02 at Osan Air Base, South Korea.*

USAF PHOTO BY AIRMAN JASON EPLEY



A1C Kevin Jenkins, a crew chief with the 605th Aircraft Maintenance Squadron, cleans the struts of a KC-10A Extender aircraft on McGuire Air Force Base, N.J., prior to ground refueling. Jenkins was working on the flight line in a 100-degree heat wave. The heat index warning was at Category 5, meaning personnel must drink at least a quart of water an hour and work 30-minutes-on and 30-minutes-off.

USAF PHOTO BY KENN MANN

Heat stroke, the most severe heat-related illness you can suffer, is a life threatening, true medical emergency. This condition is characterized by a body temperature as high as 105 degrees Fahrenheit, muscle flaccidity, involuntary limb movement, seizures, coma, a rapid shallow heartbeat, vomiting, diarrhea, and possibly hallucinations. The victim, if he or she is able to talk, will likely be irrational.

The first actions to take in addressing these heat injuries, with the exception of heat stroke, are to remove excess clothing from the individual, move them to a cooler environment if at all possible, and provide fluid and electrolyte replacement. In the case of heat stroke, the person requires emergency medical care. While you are waiting for medical personnel to arrive, you can begin taking some aggressive actions to quickly lower the person's core body temperature, such as using ice packs, or submerging them in or spraying them with cold water.



| Category               | 1       | 2       | 3       | 4       | 5     |
|------------------------|---------|---------|---------|---------|-------|
| Wet Bulb Globe Temp °F | 78-81.9 | 82-84.9 | 85-87.9 | 88-89.9 | ≥90   |
| Flag Color             | No Flag | Green   | Yellow  | Red     | Black |

Courtesy USAF publication afpam48-151. For full report go to <http://www.e-publishing.af.mil/pubfiles/af/48/afpam48-151/afpam48-151.pdf>

So what can you do to prevent this from happening to you or your coworkers? AF veteran Angela Montgomery, M.S., currently an exercise physiologist and fitness professional, maintains that the best thing anyone can do to prevent heat illnesses is to stay hydrated.

"By the time you start feeling thirsty, your body has already begun dehydrating," she says. "I cannot overemphasize the importance of drinking enough water when you're out in the heat exerting yourself, whether you're exercising or working. It takes less time than you would think, for dehydration to really make you sick."

On average, a body loses about six pints of water a day, under normal conditions, mostly through

respiration and perspiration. Normal conditions, for our purposes here, mean not exerting yourself in extreme temperatures while wearing hot and bulky extra layers of personal protective equipment. When you factor in the temperature and the extra body heat generated by the extra clothing and gear, as well as physical exertion, you can see how easily you can get dehydrated, or worse. It is absolutely critical to take in more fluids than you lose.

Something else you can do to prevent heat illness from overtaking you is educate yourself further. Do some more reading. AF Pamphlet 48-151 is full of good information. And don't forget to drink some more water before you go out.

## NOAA's National Weather Service Heat Index

Temperature (°F)

| Relative Humidity (%) | 80 | 82 | 84  | 86  | 88  | 90  | 92  | 94  | 96  | 98  | 100 | 102 | 104 | 106 | 108 | 110 |
|-----------------------|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 40                    | 80 | 81 | 83  | 85  | 88  | 91  | 94  | 97  | 101 | 105 | 109 | 114 | 119 | 124 | 130 | 136 |
| 45                    | 80 | 82 | 84  | 87  | 89  | 93  | 96  | 100 | 104 | 106 | 114 | 119 | 124 | 130 | 137 |     |
| 50                    | 81 | 83 | 85  | 88  | 91  | 95  | 99  | 103 | 108 | 113 | 118 | 124 | 131 | 137 |     |     |
| 55                    | 81 | 84 | 86  | 89  | 93  | 97  | 101 | 106 | 112 | 117 | 124 | 130 | 137 |     |     |     |
| 60                    | 82 | 84 | 88  | 91  | 95  | 100 | 105 | 110 | 116 | 123 | 129 | 137 |     |     |     |     |
| 65                    | 82 | 85 | 89  | 93  | 98  | 103 | 108 | 114 | 121 | 128 | 136 |     |     |     |     |     |
| 70                    | 83 | 86 | 90  | 95  | 100 | 105 | 112 | 119 | 126 | 134 |     |     |     |     |     |     |
| 75                    | 84 | 88 | 92  | 97  | 103 | 109 | 116 | 124 | 132 |     |     |     |     |     |     |     |
| 80                    | 84 | 89 | 94  | 100 | 106 | 113 | 121 | 129 |     |     |     |     |     |     |     |     |
| 85                    | 85 | 90 | 96  | 102 | 110 | 117 | 126 | 135 |     |     |     |     |     |     |     |     |
| 90                    | 86 | 91 | 98  | 105 | 113 | 122 | 131 |     |     |     |     |     |     |     |     |     |
| 95                    | 86 | 93 | 100 | 108 | 117 | 127 |     |     |     |     |     |     |     |     |     |     |
| 100                   | 87 | 95 | 103 | 112 | 121 | 132 |     |     |     |     |     |     |     |     |     |     |

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity



Caution



Extreme Caution



Danger



Extreme Danger

Courtesy National Oceanic & Atmospheric Administration (NOAA).

## Effects of Acclimation on Cognitive Performance in Soldiers during Exertional Heat Stress

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This study investigates the effects of exertional heat stress and acclimation status on physiological and cognitive performance. Forty male soldiers performed an exertional heat stress test (EHST) either in a cool (20°C, 16°C wet bulb globe temperature), or in a hot environment (40°C, 29°C wet bulb globe temperature), unacclimatized, or after 10 days of passive or active acclimation. Mean skin and tympanic (Tty) temperatures and heart rates (HR) measured physiological strain. A cognitive test (the computerized Cambridge Neuropsychological Test Automated Batteries attention battery) is administered before and immediately after EHST. EHST in hot conditions induced physiological heat stress (increase in Tty and HR), which caused mild deficits in attention in U group (decreased number of correct responses, and prolonged movement time). Acclimated (passive and active) soldiers suffered no detrimental effects of exertional heat stress, despite almost the same degree of heat strain, measured by Tty and HR.

### Introduction

Heat stress can be a significant problem in the military services. Common preventive measures (restriction of physical activity, taking off clothes, and moving into shade) are often impossible to obtain. Heat stress can impair both physical and mental performance.<sup>1-3</sup> Studies of cognitive performance under hot conditions are difficult to evaluate due to various methodological designs, exposure duration, skill, and acclimation level, as well as to the absence of concise theory on which experimental work can be based.<sup>4</sup>

Computerized Cambridge Neuropsychological Test Automated Batteries are a set of neuropsychological test batteries specifically designed for comparative assessment of cognition. The tests are graded in nature, avoiding ceiling effects in young, normal subjects.<sup>5</sup> Computer testing is given in a standardized form with standardized feedback and a detailed recording of accuracy and speed. Standardized scores are produced from a large pool of normative data.

It is well established that acclimation to heat produces physiological adaptations which result in decreased physiological strain and increased tolerance during exercise in the heat.<sup>6</sup> However, the effects of acclimation on cognitive performance

during exertional heat stress have been of little interest so far. The aim of this study was to investigate the effect of exertional heat stress and the influence of acclimation on physiological and cognitive responses in young soldiers.

### Subjects and Methods

Forty male soldiers (20.1 ± 0.9 years) participated in the trial after being informed of the purpose and details of the trial, any known risks and discomforts, and their right to terminate participation at will. After briefing, the soldiers gave their written informed consents to participate. Standard anthropometric measurements were conducted; baseline levels of maximal aerobic power (VO<sub>2max</sub>) were determined on treadmill.<sup>7</sup>

The investigation was conducted during winter (late November and December) in the Military Medical Academy in Belgrade. The soldiers were randomly divided into four equal groups. The first group was unacclimatized controls, who performed the exertional heat-stress test (EHST) in a cool environment (C). Another unacclimatized group performed the EHST in a hot environment (U), and the other two groups performed the same test, but after 10 days of acclimation in a climatic chamber (3 hours each day, in 35°C, relative humidity 40%, wind speed <0.1 m/s); acclimation was, in one group, conducted passively (P), and in the other actively, with 1 hour walking on a treadmill, 5.5 km/h (A). EHST consisted of walking on a motorized treadmill (5.5 km/h) either in a cool (20°C, wet bulb globe temperature (WBGT) 16°C-C group) or hot (40°C, WBGT 29°C-U, P, and A group) environment, while wearing a normal combat uniform, with a backpack filled with 20 kg of sand to simulate regular weight burden. Duration of EHST was maximally 90 minutes; the criteria for termination were: Tty 39.5°C,<sup>8</sup> heart rate (HR) 190 beats/minute, or intolerable subjective discomfort. The subjects were allowed to drink tap water at will, up to 1.5 L. Cognitive tests were administered to each soldier before and immediately after the EHST.

The soldiers were closely monitored for up to 5 hours after finishing the trial and medically examined after 2 days (ECG, blood pressure and routine blood analysis). Environmental conditions (dry bulb-temperature, WBGT, relative humidity and wind speed) were measured by MiniLab Light Laboratories (Brighton, United Kingdom). Skin temperatures were measured continuously using contact probes with transducers (precision ± 0.1°C, range 0–50°C; Ellab Instruments, Elektrolaboratoriet, Copenhagen). The thermistors were set at four locations (neck, right scapula, left hand, right shin). Mean skin temperatures (Tsk) were calculated every 5 minutes from values obtained and weighted.<sup>9</sup> Core (tympanic) temperatures (Tty) were measured discontinuously, by introduction of a thermistor into the auditory canal every 5 minutes and placing it toward the tympanic

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membrane. HR was continuously telemetrically monitored (Biotelemetry Instruments, Eagan, Minnesota) and recorded every 5 minutes.

Cognitive performance was assessed using the Computerized Cambridge Neuropsychological Test Automated Batteries, version 2.0. We used the attention battery, which includes tests of selective, divided, and sustained attention<sup>5</sup>; motor screening (MOT), reaction time (RTI), and rapid visual information processing (RVP). The tests are administered using a computer with a touch-sensitive screen and a response key was used for reaction timing. During all tests, an investigator was present to explain and supervise the tests.

Data are presented as means  $\pm$  SD. The difference was assessed by two-way analysis of variance for repeated measures and Student's *t* test for paired samples. The normal distribution was tested by Shapiro Wilk's test. SPSS 10.0 was used to process statistical material and the 0.05 level of significance was used.

**Results**

The physical characteristics of the subjects are shown in Table I. All groups were similar in all characteristics investigated. Not 1 of the 40 soldiers showed any symptoms of heat stroke during or after the EHST. Results of all medical examinations showed no sign of serious dysfunction. All soldiers in C group completed the EHST. However, only 1 soldier in U group successfully completed EHST; in the rest of the cases, tests have been terminated between 45 and 70 minutes, mostly due to reaching the ethical barrier for core temperature (*T<sub>c</sub>*) (39.5°C), or intolerable subjective discomfort. In acclimatized groups, most of the soldiers managed to finish the test; 3 soldiers in P group and 1 in A group terminated the test between 60 and 80 minutes, reaching the *T<sub>c</sub>* barrier. Even so, their subjective sensation of discomfort was tolerable and they were willing to continue the test.

Mean *T<sub>sk</sub>*, *T<sub>ty</sub>*, and HR values are presented in Figures 1, 2, and 3, respectively. In the C group, in the first 20 minutes (until sweating occurred) there was an increase in *T<sub>sk</sub>* and *T<sub>ty</sub>* and after that period there was a mild decrease in *T<sub>sk</sub>*, while *T<sub>ty</sub>* remained constant. In all groups that performed EHST in a hot environment, *T<sub>sk</sub>* was significantly higher all throughout the EHST, and the values recorded in the U group between 50 and 70 minutes were significantly higher compared to acclimatized groups (*p* < 0.05). *T<sub>ty</sub>* raised steadily in all groups that performed EHST in hot environment, with slightly lower values recorded in acclimatized groups. HR in hot conditions were increasing in all groups similarly, but the limit of 190 beats/minute was never reached. Maximal recorded HR was 163 beats/minute.

The means of the performance tasks are summarized in Table II. In the MOT test, there was no difference between responses for latency or number of errors before and after EHST, regardless of heat condition and acclimation. In the more complex RVP test,

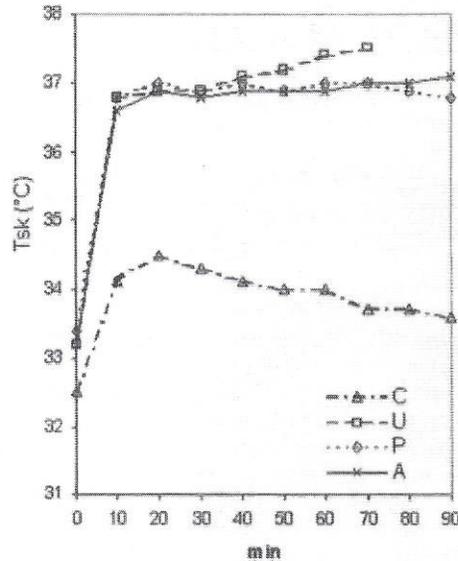


Fig. 1. *T<sub>sk</sub>* during EHST.

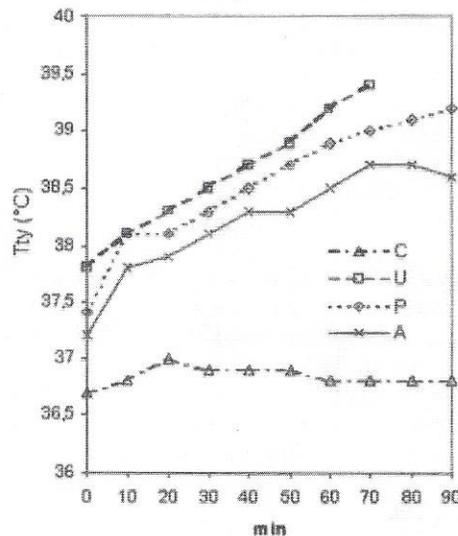


Fig. 2. *T<sub>ty</sub>* during EHST.

latency in all groups did not differ after EHST compared to baseline levels, but in the U group, there was a significant decrease in the percentage of correct responses (79.4  $\pm$  7.1% before vs. 69.7  $\pm$  10.3% after EHST; *p* < 0.05) and significant delay of movement in the RTI test, i.e., an increase in movement time (368.4  $\pm$  72.1 ms before vs. 410.1  $\pm$  80.7 ms after EHST; *p* < 0.05). The rest of the variables registered in the RTI test (percentage of correct responses and reaction time) in all groups were similar before and after EHST.

TABLE I  
PHYSICAL CHARACTERISTICS OF THE SUBJECTS

| Group | Height (m)      | Body Mass (kg) | Body Fat Content (%) | VO <sub>2max</sub> (ml/kg/min) |
|-------|-----------------|----------------|----------------------|--------------------------------|
| C     | 1.79 $\pm$ 0.05 | 78.1 $\pm$ 5.3 | 17.1 $\pm$ 4.5       | 56.6 $\pm$ 5.9                 |
| U     | 1.82 $\pm$ 0.03 | 75.9 $\pm$ 6.6 | 16.8 $\pm$ 2.4       | 62.9 $\pm$ 10.1                |
| P     | 1.84 $\pm$ 0.04 | 73.9 $\pm$ 3.4 | 15.7 $\pm$ 1.9       | 55.4 $\pm$ 5.1                 |
| A     | 1.79 $\pm$ 0.05 | 73.7 $\pm$ 9.4 | 16.9 $\pm$ 3.8       | 56.2 $\pm$ 7.7                 |

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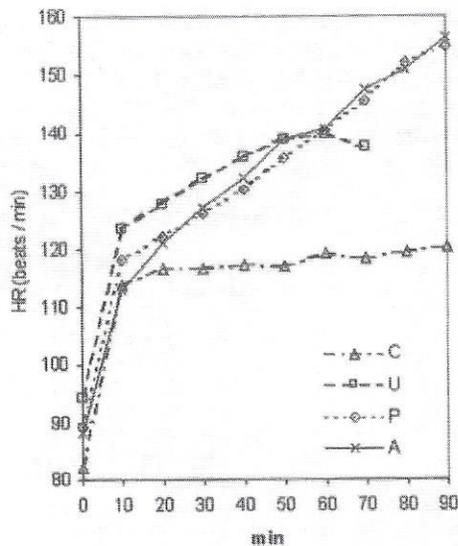


Fig. 3. HR during EHST.

Discussion

Impaired working efficiency is a well-known consequence of heat strain.<sup>10</sup> This is particularly important for military services. Core temperature is considered as a relevant indicator of thermal strain. Military training guidelines for continuous physical work times are based on achieving Tc of 40°C in acclimated individuals with appropriate fluid replacement.<sup>3</sup> In this trial, the tympanic thermometry was used as a measure of Tc, as a reliable method for monitoring changes in body temperature during exercise.<sup>11</sup> During military operational settings, even less conservative guidelines (higher Tc) can be employed<sup>3</sup>; these high Tc are possible and not so rare in real situations related to military service and deserve to be investigated. In our study, at high degree or heat strain, three unacclimated soldiers experienced subjective discomfort (generalized weakness, fatigue, and pain/heaviness in shoulders—the latest was attributed to the weight they carried) and urge to terminate the test, but acclimated soldiers did not approach levels at which their activity should be reduce.

HR values were well within the predicted maximum for their age, indicating that the workload had not exceeded their physical capabilities, considering their baseline levels of VO<sub>2max</sub>, which were relatively high. In terms of heat stress, the major advantage attributed to a higher aerobic fitness is the ability to tolerate a higher Tc at exhaustion.<sup>8</sup>

The combination of dynamic physical activity and heat stress leads to fatigue, which originates from cerebral changes (reduced neural drive and cerebral blood flow, gradual slowing of the electroencephalogram,<sup>12</sup> along with disturbances in cerebral neurotransmitter levels).<sup>13</sup> There were a number of reports of impaired neurological and neurobehavioral functions during exertional heat stress,<sup>14,15</sup> long-term memory,<sup>16</sup> and vigility.<sup>1</sup> It is well known that exercise-induced heat stroke is best defined by severe mental dysfunction, regardless of body temperature,<sup>17</sup> and may lead to long-term cognitive impairment.<sup>18</sup>

The aim of this study was to investigate the effect of exertional heat stress on attention responses and the influence of acclimation. EHST in unacclimated soldiers lowered performance in

TABLE II  
COGNITIVE PERFORMANCE BEFORE AND AFTER EHST

| Group | MOT          |               |                       |                    | RTI                |                       |              |              | RVP    |  |            |  |
|-------|--------------|---------------|-----------------------|--------------------|--------------------|-----------------------|--------------|--------------|--------|--|------------|--|
|       | Before       |               | After EHST            |                    | Before             |                       | After EHST   |              | Before |  | After EHST |  |
|       | Latency (ms) | No. of Errors | Correct Responses (%) | Reaction Time (ms) | Movement Time (ms) | Correct Responses (%) | Latency (ms) |              |        |  |            |  |
| C     | 582.5 ± 95.1 | 26.0 ± 5.4    | 96.8 ± 2.6            | 322.0 ± 44.6       | 439.6 ± 80.0       | 80.0 ± 14.7           | 420.0 ± 60.9 | 410.7 ± 30.7 |        |  |            |  |
| U     | 509.1 ± 47.7 | 28.6 ± 7.3    | 95.3 ± 3.1            | 249.3 ± 24.9       | 368.4 ± 72.1       | 79.4 ± 7.1            | 436.4 ± 32.1 | 459.4 ± 53.7 |        |  |            |  |
| P     | 537.5 ± 55.8 | 33.5 ± 14.0   | 96.7 ± 2.7            | 295.4 ± 19.8       | 360.8 ± 71.4       | 78.2 ± 14.8           | 423.6 ± 38.4 | 418.3 ± 56.6 |        |  |            |  |
| A     | 542.7 ± 45.0 | 25.2 ± 4.6    | 96.2 ± 2.7            | 307.1 ± 29.9       | 366.3 ± 76.9       | 72.8 ± 8.1            | 398.0 ± 33.6 | 398.9 ± 21.9 |        |  |            |  |

<sup>a</sup>Value of p < 0.05, before vs. after EHST.

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some tasks. However, despite the relatively high degree of heat strain, even the unacclimatized soldiers did not show any substantial deficit of attention performance. Some investigators<sup>19</sup> reported that the performance in the state of heat strain depends not only on the absolute value or the Tc, but also on the direction of its movement, i.e., performance was significantly worse as the Tc was rising compared to falling—the latter was the case in our trial. It must be also highlighted that subjects may have been stressed at the start of the trial by the uncommon computerized testing (their mean baseline scores were relatively poor), while at the end they felt more relaxed, so they might have compensated for the effect of heat stress. A similar observation was reported by Amos et al.<sup>20</sup> Subjects in C group showed a trend of improving cognitive performance after the EHST (although without statistical significance), which can also be attributed to facilitation of specific aspects of information processing by the aerobic exercise of submaximal intensity without heat stress.<sup>21</sup>

In addition, performance deficits were significant only in complex tests (RTI), so simple motor performance (assessed in the MOT test) was relatively unaffected by heat stress. This is in agreement with the opinion that heat affects cognitive performance differentially, based on the type of cognitive task. According to Hancock,<sup>22</sup> simple mental tasks show little, if any, decrement in the heat, and are frequently enhanced during brief exposures. However, substantial heat stress (30–33°C WBGT) may lead to impairment of performance in more complex tasks (perceptual motor and dual tasks).<sup>4,23</sup>

Heat acclimation is an extremely important modifiable risk factor for tolerance to exercise-induced heat stress.<sup>24</sup> In this study, 10-day acclimation led to complete prevention of the detrimental effects of exertional heat stress on attention performance. There was no significant difference between passive and active acclimation. This could be attributed to relatively high baseline levels of  $\dot{V}O_{2max}$ , but, since we did not measure  $\dot{V}O_{2max}$  after acclimation, we can only assume that short-time aerobic exercise of moderate intensity was not sufficient for further improvement of thermotolerance.

It would be interesting to investigate the improvement of cognitive functions day-by-day during acclimatization, but some authors<sup>25</sup> have indicated that frequent repeated testing can lead to a "training" phenomenon: the more experienced the subject is, the less likely he is to be disturbed by thermal stress.

### Conclusions

This study demonstrated effects of physical activity in a hot environment on physiological parameters, as shown by an increase in Tty and HR. This physiological heat stress caused mild deficits in attention in unacclimatized soldiers, as shown by a fall in the percentage of correct responses, and a delay in movement responses to the test stimuli. In addition, performance deficits were significant only in complex tests, so the simple

motor performance was relatively unaffected by physical activity in the heat. Ten-day acclimation in a duration of 3 hours daily, either passive or active, has influenced both physiological and cognitive response, and acclimatized soldiers suffered no detrimental effects of exertional heat stress, despite almost the same degree of heat strain, measured by Tty and HRs.

### References

1. Faerevik H, Reinertsen RE: Effects of wearing aircrew protective clothing on physiological and cognitive responses under various ambient conditions. *Ergonomics* 2003; 46: 780–93.
2. Froom P, Caine Y, Shochat I, Ribak J: Heat stress and helicopter pilot errors. *J Occup Med* 1993; 35: 720–4.
3. Technical Bulletin (TBMED) 2003; 507/AFPAM (I), pp 48–152.
4. Hancock PA, Vasmatazidis I: Effects of heat stress on cognitive performance: the current state of knowledge. *Int J Hyperthermia* 2003; 19: 355–72.
5. Fray PJ, Robbins TW, Sahakian BJ: Neuropsychiatric applications of CANTAB. *Int J Geriatr Psychiatry* 1996; 11: 329–36.
6. Cheung SS, McLellan TM: Heat acclimation, aerobic fitness, and hydration effects on tolerance during uncompensable heat stress. *J Appl Physiol* 1998; 84: 1731–9.
7. Bruce RA: Exercise testing of patients with coronary heart disease: principles and normal standards for evaluation. *Ann Clin Res* 1971; 3: 323–32.
8. Selkirk GA, McLellan TM: Influence of aerobic fitness and body fatness on tolerance to uncompensable heat stress. *J Appl Physiol* 2001; 91: 2055–63.
9. ISO 9886: Evaluation of thermal strain by physiological measurements. 1992.
10. Donaldson GC, Keatinge WR, Saunders RD: Cardiovascular responses to heat stress and their adverse consequences in healthy and vulnerable human populations. *Int J Hyperthermia* 2003; 19: 225–35.
11. Newsham KR, Saunders JE, Nordin ES: Comparison of rectal and tympanic thermometry during exercise. *South Med J* 2002; 95: 804–10.
12. Nielsen B, Nybo L: Cerebral changes during exercise in the heat. *Sports Med* 2003; 33: 1–11.
13. Cheung SS, Sleivert GG: Multiple triggers for hyperthermic fatigue and exhaustion. *Exerc Sport Sci Rev* 2004; 32: 100–6.
14. Chia SE, Teo KJ: Postural stability and neurobehavioural effects of heat exhaustion among adult men. *Neurotoxicol Teratol* 2001; 23: 659–64.
15. Chia SE, Teo KJ: Prognosis of adult men with heat exhaustion with regard to postural stability and neurobehavioural effects: a 6-month follow-up study. *Neurotoxicol Teratol* 2003; 25: 503–8.
16. Cian C, Barraud PA, Mellin B, Raphael C: Effects of fluid ingestion on cognitive function after heat stress or exercise-induced dehydration. *Int J Psychophysiol* 2001; 42: 243–51.
17. Booker RJ, Bricknell MCM: Heat illness—recent developments. *J R Army Med Corps* 2002; 148: 11–8.
18. Romero JJ, Clement PF, Belden C: Neuropsychological sequelae of heat stroke: report of three cases and discussion. *Milit Med* 2000; 165: 500–3.
19. Allan JR, Gibson TM: Separation of the effects of raised skin and core temperature on performance of a pursuit rotor task. *Aviat Space Environ Med* 1979; 50: 678–82.
20. Amos D, Hansen R, Lau WM, Michalski JF: Physiological and cognitive performance of soldiers conducting routine patrol and reconnaissance operations in the tropics. *Milit Med* 2000; 165: 961–6.
21. Tomporowski PD: Effects of acute bouts of exercise on cognition. *Acta Physiol* 2003; 112: 297–324.
22. Hancock PA: Task categorizations and the limits of human performance in extreme heat. *Aviat Space Environ Med* 1982; 53: 778–84.
23. Chase B, Karwowski W, Benedict ME, Quesada PM, Irwin-Chase HM: A study of computer-based task performance under thermal stress. *Int J Occup Saf Ergon* 2003; 9: 5–15.
24. Coris EE, Ramirez AM, Van Durme DJ: Heat illness in athletes. *Sports Med* 2004; 34: 9–16.
25. Hancock PA, Williams G, Manning CM, Miyake S: Influence of task demand characteristics on workload and performance. *Int J Aviat Psychol* 1995; 5: 63–86.

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## Protecting Workers from Heat Stress

### Heat Illness

Exposure to heat can cause illness and death. The most serious heat illness is heat stroke. Other heat illnesses, such as heat exhaustion, heat cramps and heat rash, should also be avoided.

There are precautions your employer should take any time temperatures are high and the job involves physical work.

### Risk Factors for Heat Illness

- High temperature and humidity, direct sun exposure, no breeze or wind
- Low liquid intake
- Heavy physical labor
- Waterproof clothing
- No recent exposure to hot workplaces

### Symptoms of Heat Exhaustion

- Headache, dizziness, or fainting
- Weakness and wet skin
- Irritability or confusion
- Thirst, nausea, or vomiting

### Symptoms of Heat Stroke

- May be confused, unable to think clearly, pass out, collapse, or have seizures (fits)
- May stop sweating

### To Prevent Heat Illness, Your Employer Should

- Provide training about the hazards leading to heat stress and how to prevent them.
- Provide a lot of cool water to workers close to the work area. At least one pint of water per hour is needed.



For more information:

**OSHA<sup>®</sup>** Occupational  
Safety and Health  
Administration

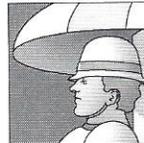
U.S. Department of Labor

[www.osha.gov](http://www.osha.gov) (800) 321-OSHA (6742)

OSHA 3154-09-11R

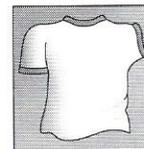
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- Schedule frequent rest periods with water breaks in shaded or air-conditioned areas.
- Routinely check workers who are at risk of heat stress due to protective clothing and high temperature.
- Consider protective clothing that provides cooling.



## How You Can Protect Yourself and Others

- Know signs/symptoms of heat illnesses; monitor yourself; use a buddy system.
- Block out direct sun and other heat sources.
- Drink plenty of fluids. Drink often and BEFORE you are thirsty. Drink water every 15 minutes.
- Avoid beverages containing alcohol or caffeine.
- Wear lightweight, light colored, loose-fitting clothes.



## What to Do When a Worker is Ill from the Heat

- Call a supervisor for help. If the supervisor is not available, call 911.
- Have someone stay with the worker until help arrives.
- Move the worker to a cooler/shaded area.
- Remove outer clothing.
- Fan and mist the worker with water; apply ice (ice bags or ice towels).
- Provide cool drinking water, if able to drink.

**IF THE WORKER IS NOT ALERT or seems confused, this may be a heat stroke. CALL 911 IMMEDIATELY and apply ice as soon as possible.**

**If you have any questions or concerns, call OSHA at 1-800-321-OSHA (6742).**

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## HEAT STRESS



### NIOSH Fast Facts



**Protecting Yourself from Heat Stress** [Print](#) or [order](#) this free card for easy access to important safety information.

### Overview

Workers who are exposed to extreme heat or work in hot environments may be at risk of heat stress. Exposure to extreme heat can result in occupational illnesses and injuries. Heat stress can result in heat stroke, heat exhaustion, heat cramps, or heat rashes. Heat can also increase the risk of injuries in workers as it may result in sweaty palms, fogged-up safety glasses, and dizziness. Burns may also occur as a result of accidental contact with hot surfaces or steam.

Workers at risk of heat stress include outdoor workers and workers in hot environments such as firefighters, bakery workers, farmers, construction workers, miners, boiler room workers, factory workers, and others. Workers at greater risk of heat stress include those who are 65 years of age or older, are overweight, have heart disease or high blood pressure, or take medications that may be affected by extreme heat.

Prevention of heat stress in workers is important. Employers should provide training to workers so they understand what heat stress is, how it affects their health and safety, and how it can be prevented.

## Types of Heat Stress

[Heat Stroke](#) | [Heat Exhaustion](#) | [Heat Syncope](#) | [Heat Cramps](#) | [Heat Rash](#)

### Heat Stroke

Heat stroke is the most serious heat-related disorder. It occurs when the body becomes unable to control its temperature: the body's temperature rises rapidly, the sweating mechanism fails, and the body is unable to cool down. When heat stroke occurs, the body temperature can rise to 106 degrees Fahrenheit or higher within 10 to 15 minutes. Heat stroke can cause death or permanent disability if emergency treatment is not given.

### Symptoms

Symptoms of heat stroke include:

- Hot, dry skin or profuse sweating
- Hallucinations
- Chills
- Throbbing headache
- High body temperature
- Confusion/dizziness
- Slurred speech

### First Aid

Take the following steps to treat a worker with heat stroke:

- Call 911 and notify their supervisor.
- Move the sick worker to a cool shaded area.
- Cool the worker using methods such as:
  - Soaking their clothes with water.
  - Spraying, sponging, or showering them with water.
  - Fanning their body.

### Heat Exhaustion

Heat exhaustion is the body's response to an excessive loss of the water and salt, usually through excessive sweating. Workers most prone to heat exhaustion are those that are elderly, have high blood pressure, and those working in a hot environment.

### Symptoms

Symptoms of heat exhaustion include:

- Heavy sweating
- Extreme weakness or fatigue
- Dizziness, confusion
- Nausea
- Clammy, moist skin

- Pale or flushed complexion
- Muscle cramps
- Slightly elevated body temperature
- Fast and shallow breathing

## First Aid

Treat a worker suffering from heat exhaustion with the following:

- Have them rest in a cool, shaded or air-conditioned area.
- Have them drink plenty of water or other cool, nonalcoholic beverages.
- Have them take a cool shower, bath, or sponge bath.

## Heat Syncope

Heat syncope is a fainting (syncope) episode or dizziness that usually occurs with prolonged standing or sudden rising from a sitting or lying position. Factors that may contribute to heat syncope include dehydration and lack of acclimatization.

## Symptoms

Symptoms of heat syncope include:

- Light-headedness
- Dizziness
- Fainting

## First Aid

Workers with heat syncope should:

- Sit or lie down in a cool place when they begin to feel symptoms.
- Slowly drink water, clear juice, or a sports beverage.

## Heat Cramps

Heat cramps usually affect workers who sweat a lot during strenuous activity. This sweating depletes the body's salt and moisture levels. Low salt levels in muscles causes painful cramps. Heat cramps may also be a symptom of heat exhaustion.

## Symptoms

Muscle pain or spasms usually in the abdomen, arms, or legs.

## First Aid

Workers with heat cramps should:

- Stop all activity, and sit in a cool place.
- Drink clear juice or a sports beverage.
- Do not return to strenuous work for a few hours after the cramps subside because further exertion may lead to heat exhaustion or heat stroke.
- Seek medical attention if any of the following apply:
  - The worker has heart problems.

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- The worker is on a low-sodium diet.
- The cramps do not subside within one hour.

## Heat Rash

Heat rash is a skin irritation caused by excessive sweating during hot, humid weather.

## Symptoms

Symptoms of heat rash include:

- Heat rash looks like a red cluster of pimples or small blisters.
- It is more likely to occur on the neck and upper chest, in the groin, under the breasts, and in elbow creases.

## First Aid

Workers experiencing heat rash should:

- Try to work in a cooler, less humid environment when possible.
- Keep the affected area dry.
- Dusting powder may be used to increase comfort.

## Recommendations for Employers

Employers should take the following steps to protect workers from heat stress:

- Schedule maintenance and repair jobs in hot areas for cooler months.
- Schedule hot jobs for the cooler part of the day.
- Acclimatize workers by exposing them for progressively longer periods to hot work environments.
- Reduce the physical demands of workers.
- Use relief workers or assign extra workers for physically demanding jobs.
- Provide cool water or liquids to workers.
  - Avoid alcohol, and drinks with large amounts of caffeine or sugar.
- Provide rest periods with water breaks.
- Provide cool areas for use during break periods.
- Monitor workers who are at risk of heat stress.
- Provide heat stress training that includes information about:
  - Worker risk
  - Prevention
  - Symptoms
  - The importance of monitoring yourself and coworkers for symptoms
  - Treatment
  - Personal protective equipment

## Recommendations for Workers

Workers should avoid exposure to extreme heat, sun exposure, and high humidity when possible. When these exposures cannot be avoided, workers should take the following steps to prevent heat stress:

- Wear light-colored, loose-fitting, breathable clothing such as cotton.

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- Avoid non-breathing synthetic clothing.
- Gradually build up to heavy work.
- Schedule heavy work during the coolest parts of day.
- Take more breaks in extreme heat and humidity.
  - Take breaks in the shade or a cool area when possible.
- Drink water frequently. Drink enough water that you never become thirsty. Approximately 1 cup every 15-20 minutes.
- Avoid alcohol, and drinks with large amounts of caffeine or sugar.
- Be aware that protective clothing or personal protective equipment may increase the risk of heat stress.
- Monitor your physical condition and that of your coworkers.

## CDC Resources

[Preventing Heat-related Illness or Death of Outdoor Workers](#)

[OSHA-NIOSH INFOSHEET: Protecting Workers from Heat Illness](#)

[MMWR: Heat-Related Deaths among Crop Workers, 1992-2006](#)

[CDC: Extreme Heat](#)

Additional information on heat stress illnesses and prevention.

[NIOSH: Criteria for a Recommended Standard: Occupational Exposure to Hot Environments \(Revised Criteria 1986\)](#)

This document presents the criteria, techniques, and procedures for the assessment, evaluation, and control of occupational heat stress by engineering and preventive work practices. Included are ways of predicting health risks, procedures for control of heat stress, and techniques for prevention and treatment of heat-related illnesses.

## Health Hazard Evaluations

- [Health Hazard Evaluation Report, HETA 2006-0307-3139](#)  [PDF - 3.67MB], Heat Stress and Strain Evaluation Among Aluminum Potroom Employees – Texas
- [Health Hazard Evaluation Report, HETA 2005-0215-3099](#)  [PDF - 3.89MB], Evaluation of Heat and Carbon Monoxide Exposures to Border Protection Officers at Ports of Entry
- [Health Hazard Evaluation Report, HETA 2004-0334-3017](#), Transportation Security Administration, Palm Beach International Airport, West Palm Beach, Florida
- [Health Hazard Evaluation Report, HETA 2003-0311-3052](#) , Evaluation of Heat Stress at a Glass Bottle Manufacturer, Lapel, Indiana
- [Health Hazard Evaluation Report, HETA 2000-0061-2885](#), United States Air Force, Seymour Johnson Air Force Base, Goldsboro, North Carolina

## Fatality Assessment and Control Evaluation (FACE) Program

- [Landscape Mowing Assistant Dies from Heat Stroke](#)
- [Migrant Farm Worker Dies from Heat Stroke While Working on a Tobacco Farm – North Carolina](#)
- [Fire Fighter Dies of Heat Stroke While Making a Fire Line During a Wildland Fire in California](#)
- [Construction Laborer Dies from Heat Stroke at End of Workday](#)

Additional reports can be found by searching for "heat stress" on [FACE](#).

## Other Government Resources

### [Occupational Safety and Health Administration \(OSHA\) Safety and Health Topics: Heat Stress](#)

Provides a guide to information regarding the recognition, evaluation, control, and compliance actions involving heat stress.

### [OSHA Technical Manual Section III: Chapter 4 - Heat Stress](#)

Provides descriptions of heat disorders, investigative guidelines, sampling methods, control, and PPE.

### [OSHA Sawmills eTool: Heat Stresses](#)

Provides information on the hazards of heat stress and possible solutions or controls.

### [OSHA Quick Card: Heat Stress](#) [PDF - 2.37MB]

Provides heat stress factors, symptoms, prevention tips, and first aid recommendations.

### [OSHA Fact Sheet: Protecting Workers from Effects of Heat](#) [PDF - 22 KB]

Provides information that will help workers understand what heat stress is, how it may affect their health and safety, and how it can be prevented.

### [OSHA Fact Sheet: Working Outdoors in Warm Climates](#) [PDF - 25 KB]

Hot summer months pose special hazards for outdoor workers who must protect themselves against heat, sun exposure, and other hazards. Employers and employees should know the potential hazards in their workplaces and how to manage them.

### [National Oceanic & Atmospheric Administration's \(NOAA\) National Weather Service: Heat Index](#)

### [NOAA: Heat Wave - A Major Summer Killer](#) [PDF - 268 KB]

Provides general information regarding the recognition and control of heat stress.

### [Mine Safety & Health Administration \(MSHA\): Heat Stress - What to Do.](#)

Provides documents related to heat stress in the mining industry.

### [United States Department of Agriculture \(USDA\): Wildland Fire Safety - Heat Stress](#)

This brochure focuses on the risks of heat stress, and what the firefighter should do to minimize those risks.

### [U.S. Army: Heat Index Calculator](#)

## Additional Resources

### [American Conference of Governmental Industrial Hygienists: Product Store - Threshold Limit Values and Biological Exposure Indices](#)

[Purchase this document](#)

### [American National Standards Institute \(ANSI\) - Ergonomics of the Thermal Environment: Analytical Determination and Interpretation of Heat Stress Using Calculation of the Predicted Heat Strain](#)

This document specifies a method for the analytical evaluation and interpretation of the thermal stress experienced by a subject in a hot environment. It describes a method for predicting the sweat rate and the internal core temperature that the human body will develop

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in response to the working conditions.

[Purchase this document](#)

[ANSI - Ergonomics of the Thermal Environment: Medical Supervision of Individuals Exposed to Extreme Hot or Cold Environments](#)

This International Standard provides advice to those concerned with the safety of human exposures to extreme hot or cold thermal environments.

[Purchase this document](#)

[ANSI - Hot environments: Estimation of the Heat Stress on Working Man, Based on the WBGT-index \(Wet Bulb Globe Temperature\)](#)

This document gives a method, which can easily be used in an industrial environment for evaluating the stresses on a individual. It applies to the evaluation of the mean effect of heat on man during a period representative of his activity but it does not apply to very short periods, nor to zones of comfort.

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## NASD

- [NASD: Keep Cool](#)  
Outdoor worker flyer about heat stress.
- [NASD: Dangers of Heat Stress](#)  
Provides a script that can be used to deliver a 15-minute training session to employees. The text explains the impact that hot weather work can have on health, describes preventive measures, and touches briefly on first aid.  
[En Español](#)
- [NASD: Heat Stress](#)  
A flyer that will enable the reader with information to be able to identify symptoms of heat stroke and exhaustion, and know the emergency procedures for both.  
[En Español](#)

[Texas A&M University - Texas Cooperative Extension: Coping with Hot Work Environments](#)  
[En Español](#)

## Related Links

- [Cold Stress](#)
- [UV Radiation](#)

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Merck Manual > Health Care Professionals > Injuries; Poisoning > Heat Illness

## Heat Exhaustion

*Heat exhaustion is a non-life-threatening clinical syndrome of weakness, malaise, nausea, syncope, and other nonspecific symptoms caused by heat exposure. Thermoregulation is not impaired. IV fluids and electrolyte replacement are needed.*

Heat exhaustion is caused by water and electrolyte imbalance due to heat exposure, with or without exertion.

Rarely, severe heat exhaustion after hard work may be complicated by rhabdomyolysis, myoglobinuria, acute renal failure, and disseminated intravascular coagulation.

### Symptoms and Signs

Symptoms are often vague, and patients may not realize that heat is the cause. Symptoms may include weakness, dizziness, headache, nausea, and sometimes vomiting. Syncope due to standing for long periods in the heat (heat syncope) is common and may mimic cardiovascular disorders. On examination, patients appear tired and are usually sweaty and tachycardic. Mental status is typically normal, unlike in heatstroke. Temperature is usually normal and, when elevated, usually does not exceed 40° C.

### Diagnosis

- Clinical evaluation

Diagnosis is clinical and requires exclusion of other possible causes (eg, hypoglycemia, acute coronary syndrome, various infections). Laboratory testing is required only if needed to rule out such disorders.

### Treatment

- IV fluid and electrolyte replacement

Treatment involves removing patients to a cool environment, having them lie flat, and giving IV fluid and electrolyte replacement therapy, typically using 0.9% saline solution; oral rehydration does not provide sufficient electrolytes. Rate and volume of rehydration are guided by age, underlying disorders, and clinical response. Replacement of 1 to 2 L at 500 mL/h is often adequate. Elderly patients and patients with heart disorders may require only slightly lower rates; patients with suspected hypovolemia may require higher rates initially. External cooling measures (see [Heat Illness: Treatment](#)) are usually not required. However, if patients with heat exhaustion have a core temperature of ≥ 40° C, measures may be taken to reduce it.

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# Heatstroke

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## Background

Heat illness may be viewed as a continuum of illnesses relating to the body's inability to cope with heat. It includes minor illnesses, such as heat edema, heat rash (ie, prickly heat), heat cramps, and tetany, as well as heat syncope and heat exhaustion. Heatstroke is the most severe form of the heat-related illnesses and is defined as a body temperature higher than 41.1°C (106°F) associated with neurologic dysfunction.

Two forms of heatstroke exist. Exertional heatstroke (EHS) generally occurs in young individuals who engage in strenuous physical activity for a prolonged period of time in a hot environment. Classic nonexertional heatstroke (NEHS) more commonly affects sedentary elderly individuals, persons who are chronically ill, and very young persons. Classic NEHS occurs during environmental heat waves and is more common in areas that have not experienced a heat wave in many years. Both types of heatstroke are associated with a high morbidity and mortality, especially when therapy is delayed.

With the influence of global warming, it is predicted that the incidence of heatstroke cases and fatalities will also become more prevalent. Because behavioral responses are important in the management of temperature elevations, heatstroke may be entirely preventable.

## Pathophysiology

Despite wide variations in ambient temperatures, humans and other mammals can maintain a constant body temperature by balancing heat gain with heat loss. When heat gain overwhelms the body's mechanisms of heat loss, the body temperature rises, and a major heat illness ensues. Excessive heat denatures proteins, destabilizes phospholipids and lipoproteins, and liquefies membrane lipids, leading to cardiovascular collapse, multiorgan failure, and, ultimately, death. The exact temperature at which cardiovascular collapse occurs varies among individuals because coexisting disease, drugs, and other factors may contribute to or delay organ dysfunction. Full recovery has been observed in patients with temperatures as high as 46°C, and death has occurred in patients with much lower temperatures. Temperatures exceeding 106°F or 41.1°C generally are catastrophic and require immediate aggressive therapy.

Heat may be acquired by a number of different mechanisms. At rest, basal metabolic processes produce approximately 100 kcal of heat per hour or 1 kcal/kg/h. These reactions can raise the body temperature by 1.1°C/h if the heat dissipating mechanisms are nonfunctional. Strenuous physical activity can increase heat production more than 10-fold to levels exceeding 1000 kcal/h. Similarly, fever, shivering, tremors, convulsions, thyrotoxicosis, sepsis, sympathomimetic drugs, and many other conditions can increase heat production, thereby increasing body temperature.

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The body also can acquire heat from the environment through some of the same mechanisms involved in heat dissipation, including conduction, convection, and radiation. These mechanisms occur at the level of the skin and require a properly functioning skin surface, sweat glands, and autonomic nervous system, but they also may be manipulated by behavioral responses. Conduction refers to the transfer of heat between 2 surfaces with differing temperatures that are in direct contact. Convection refers to the transfer of heat between the body's surface and a gas or fluid with a differing temperature. Radiation refers to the transfer of heat in the form of electromagnetic waves between the body and its surroundings. The efficacy of radiation as a means of heat transfer depends on the angle of the sun, the season, and the presence of clouds, among other factors. For example, during summer, lying down in the sun can result in a heat gain of up to 150 kcal/h.

Under normal physiologic conditions, heat gain is counteracted by a commensurate heat loss. This is orchestrated by the hypothalamus, which functions as a thermostat, guiding the body through mechanisms of heat production or heat dissipation, thereby maintaining the body temperature at a constant physiologic range. In a simplified model, thermosensors located in the skin, muscles, and spinal cord send information regarding the core body temperature to the anterior hypothalamus, where the information is processed and appropriate physiologic and behavioral responses are generated. Physiologic responses to heat include an increase in the blood flow to the skin (as much as 8 L/min), which is the major heat-dissipating organ; dilatation of the peripheral venous system; and stimulation of the eccrine sweat glands to produce more sweat.

As the major heat-dissipating organ, the skin can transfer heat to the environment through conduction, convection, radiation, and evaporation. Radiation is the most important mechanism of heat transfer at rest in temperate climates, accounting for 65% of heat dissipation, and it can be modulated by clothing. At high ambient temperatures, conduction becomes the least important of the 4 mechanisms, while evaporation, which refers to the conversion of a liquid to a gaseous phase, becomes the most effective mechanism of heat loss.

The efficacy of evaporation as a mechanism of heat loss depends on the condition of the skin and sweat glands, the function of the lung, ambient temperature, humidity, air movement, and whether or not the person is acclimated to the high temperatures. For example, evaporation does not occur when the ambient humidity exceeds 75% and is less effective in individuals who are not acclimated. Nonacclimated individuals can only produce 1 L of sweat per hour, which only dispels 580 kcal of heat per hour, whereas acclimated individuals can produce 2-3 L of sweat per hour and can dissipate as much as 1740 kcal of heat per hour through evaporation. Acclimatization to hot environments usually occurs over 7-10 days and enables individuals to reduce the threshold at which sweating begins, increase sweat production, and increase the capacity of the sweat glands to reabsorb sweat sodium, thereby increasing the efficiency of heat dissipation.

When heat gain exceeds heat loss, the body temperature rises. Classic heatstroke occurs in individuals who lack the capacity to modulate the environment (eg, infants, elderly individuals, individuals who are chronically ill). Furthermore, elderly persons and patients with diminished cardiovascular reserves are unable to generate and cope with the physiologic responses to heat stress and, therefore, are at risk of heatstroke. Patients with skin diseases and those taking medications that interfere with sweating also are at increased risk for heatstroke because they are unable to dissipate heat adequately. Additionally, the redistribution of blood flow to the periphery, coupled with the loss of fluids and electrolytes in sweat, place a tremendous burden on the heart, which ultimately may fail to maintain an adequate cardiac output, leading to additional morbidity and mortality.

Factors that interfere with heat dissipation include an inadequate intravascular volume, cardiovascular dysfunction, and abnormal skin. Additionally, high ambient temperatures, high ambient humidity, and many drugs can interfere with heat dissipation, resulting in a major heat illness. Similarly, hypothalamic dysfunction may alter temperature regulation and may result in an unchecked rise in temperature and heat illness.

On a cellular level, many theories have been hypothesized and clinically scrutinized. Generally speaking, heat directly influences the body on a cellular level by interfering with cellular processes along with denaturing proteins and cellular membranes. In turn, an array of inflammatory cytokines and heat shock proteins (HSPs) (HSP-70 in particular, which allows the cell to endure the stress of its environment), are produced. If the stress continues, the cell will succumb to the stress (apoptosis) and die. Certain preexisting factors, such as age, genetic makeup, and the nonacclimatized individual, may allow progression from heat stress to heatstroke, multiorgan-dysfunction syndrome (MODS), and ultimately death. Progression to heatstroke may occur through thermoregulatory failure, an amplified acute-phase response, and alterations in the expression of HSPs.

An index used by some, including the American College of Sports Medicine, is the Wet Bulb Globe Temperature (WBGT). It is an environmental heat stress index used to evaluate the risk of heat-related illness on an individual. It is calculated using 3 parameters: temperature, humidity, and radiant heat. There is low risk if the WBGT is < 65 °F, moderate risk if it is between 65-73 °F, high risk if between 73-82 °F, and very high risk >82 °F.

## Epidemiology

## Frequency

### United States

In the United States, heat waves claim more lives each year than all other weather-related exposures combined (hurricanes, tornadoes, floods, and earthquakes).<sup>[1]</sup> According to the Centers for Disease Control and Prevention, 8,015 deaths were attributed to excessive heat exposure from 1979-2003, or an average of approximately 334 deaths per year.<sup>[2]</sup> Heatstroke and deaths from excessive heat exposure are more common during summers with prolonged heat waves. For example, during the heat wave of 1980 (a record year for heat), 1700 deaths were attributed to heat, compared to only 148 deaths attributed to heat the previous year. Persons older than 65 years accounted for at least 44% of cases. The numbers published by the NCHS are believed to grossly underestimate the true incidence of heat-related deaths because death rates from other causes (eg, cardiovascular disease, respiratory disease) also increase during the summer, and especially during heat waves.

### International

Heatstroke is uncommon in subtropical climates. The condition is recognized increasingly in countries that experience heat waves rarely (eg, Japan), and it commonly affects people who undertake a pilgrimage to Mecca, especially when the pilgrims arrive from a cold environment. In 1998, one of the worst heat waves to strike India in 50 years resulted in more than 2600 deaths in 10 weeks. Unofficial reports described the number of deaths as almost double that figure.

## Mortality/Morbidity

Morbidity and mortality from heatstroke are related to the duration of the temperature elevation. When therapy is delayed, the mortality rate may be as high as 80%; however, with early diagnosis and immediate cooling, the mortality rate can be reduced to 10%. Mortality is highest among the elderly population, patients with preexisting disease, those confined to a bed, and those who are socially isolated.

## Race

With the same risk factors and under the same environmental conditions, heatstroke affects all races equally. However, because of differences in social advantages, the annual death rate due to environmental conditions is more than 3 times higher in blacks than in whites.

## Sex

With the same risk factors and under the same environmental conditions, heatstroke affects both genders equally. However, because of gender differences in the workforce, the annual death rate due to environmental conditions is 2 times higher in men than in women.

## Age

Infants, children, and elderly persons have a higher incidence of heatstroke than young, healthy adults.

Infants and children are at risk for heat illness due to inefficient sweating, a higher metabolic rate, and their inability to care for themselves and control their environment.

Elderly persons also are at increased risk for heat-related illnesses because of their limited cardiovascular reserves, preexisting illness, and use of many medications that may affect their volume status or sweating ability. In addition, elderly people who are unable to care for themselves are at increased risk for heatstroke, presumably because of their inability to control their environment.

EHS is the second most common cause of death among high school athletes, surpassed only by spinal cord injury. Lack of acclimatization is a major risk factor for EHS in young adults.

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## References

- Centers for Disease Control and Prevention. Heat Waves. Available at <http://www.cdc.gov/climatechange/effects/heat.htm>. Accessed July 2009.
- Centers for Disease Control and Prevention. Extreme Heat: A Prevention Guide to Promote Your Personal Health and Safety. Updated July 31, 2009. Available at [http://emergency.cdc.gov/disasters/extremeheat/heat\\_guide.asp](http://emergency.cdc.gov/disasters/extremeheat/heat_guide.asp).
- National Center for Catastrophic Injury Research. Catastrophic sport injury 28th annual report. University of North Carolina. Available at <http://www.unc.edu/depts/nccsi/index.htm>.
- American College of Sports Medicine Joint Statement. National Athletic Trainers' Association. Inter-Association Task Force on Exertional Heat Illnesses Consensus Statement. 2003. Available at <http://www.nata.org/sites/default/files/inter-association-task-force-exertional-heat-illness.pdf>. Accessed August 13, 2010.
- Mazerolle SM, Pinkus DE, Casa DJ, et al. Evidence-based medicine and the recognition and treatment of exertional heat stroke, part II: a perspective from the clinical athletic trainer. *J Athl Train*. Sep-Oct 2011;46(5):533-42. [Medline]. [Full Text].
- Mazerolle SM, Ganio MS, Casa DJ, Vingren J, Klau J. Is oral temperature an accurate measurement of

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- deep body temperature? A systematic review. *J Athl Train*. Sep-Oct 2011;46(5):566-73. [Medline]. [Full Text].
7. Heled Y, Rav-Acha M, Shani Y, Epstein Y, Moran DS. The "golden hour" for heatstroke treatment. *Mil Med*. Mar 2004;169(3):184-6. [Medline].
  8. Bouchama A, Dehbi M, Chaves-Carballo E. Cooling and hemodynamic management in heatstroke: practical recommendations. *Critical Care 2007* [serial online]. 05/12/07;11 (issue 3):1-17. Accessed 02/03/07. Available at <http://ccforum.com/content/11/3/R54>.
  9. Akhtar MJ, al-Nozha M, al-Harathi S, Nouh MS. Electrocardiographic abnormalities in patients with heat stroke. *Chest*. Aug 1993;104(2):411-4. [Medline].
  10. Ash CJ, Cook JR, McMurry TA, Auner CR. The use of rectal temperature to monitor heat stroke. *Mo Med*. May 1992;89(5):283-8. [Medline].
  11. Armstrong LE, De Luca JP, Hubbard RW. Time course of recovery and heat acclimation ability of prior exertional heatstroke patients. *Med Sci Sports Exerc*. Feb 1990;22(1):36-48. [Medline].
  12. Bouchama A, Cafegi A, Devol EB, Labdi O, el-Assil K, Seraj M. Ineffectiveness of dantrolene sodium in the treatment of heatstroke. *Crit Care Med*. Feb 1991;19(2):176-80. [Medline].
  13. Bouchama A, Hammami MM, Haq A, Jackson J, al-Sedairy S. Evidence for endothelial cell activation/injury in heatstroke. *Crit Care Med*. Jul 1996;24(7):1173-8. [Medline].
  14. Bouchama A, Knochel JP. Heat stroke. *N Engl J Med*. Jun 20 2002;346(25):1978-88. [Medline].
  15. Chou YT, Lai ST, Lee CC, Lin MT. Hypothermia attenuates circulatory shock and cerebral ischemia in experimental heatstroke. *Shock*. Apr 2003;19(4):388-93. [Medline].
  16. Costrini A. Emergency treatment of exertional heatstroke and comparison of whole body cooling techniques. *Med Sci Sports Exerc*. Feb 1990;22(1):15-8. [Medline].
  17. Dahmash NS, al Harthi SS, Akhtar J. Invasive evaluation of patients with heat stroke. *Chest*. Apr 1993;103(4):1210-4. [Medline].
  18. Easterling DR, Meehl GA, Parmesan C, Changnon SA, Karl TR, Mearns LO. Climate extremes: observations, modeling, and impacts. *Science*. Sep 22 2000;289(5487):2068-74. [Medline].
  19. Eichner ER. Treatment of suspected heat illness. *Int J Sports Med*. Jun 1998;19 Suppl 2:S150-3. [Medline].
  20. el-Kassimi FA, Al-Mashhadani S, Abdullah AK, Akhtar J. Adult respiratory distress syndrome and disseminated intravascular coagulation complicating heat stroke. *Chest*. Oct 1986;90(4):571-4. [Medline].
  21. Epstein Y, Moran DS, Shapiro Y, Sohar E, Shemer J. Exertional heat stroke: a case series. *Med Sci Sports Exerc*. Feb 1999;31(2):224-8. [Medline].
  22. Fish PD, Bennett GC, Millard PH. Heatwave morbidity and mortality in old age. *Age Ageing*. Jul 1985;14(4):243-5. [Medline].
  23. Hassanein T, Razack A, Gavalier JS, Van Thiel DH. Heatstroke: its clinical and pathological presentation, with particular attention to the liver. *Am J Gastroenterol*. Oct 1992;87(10):1382-9. [Medline].
  24. Howe AS, Boden BP. Heat-related illness in athletes. *Am J Sports Med*. Aug 2007;35(8):1384-95. [Medline].
  25. Hubbard RW. The role of exercise in the etiology of exertional heatstroke. *Med Sci Sports Exerc*. Feb 1990;22(1):2-5. [Medline].
  26. Hubbard RW, Gaffin SL, Squire DL. Heat-related illnesses. In: Auerbach P, ed. *Wilderness Medicine: Management of Wilderness and Environmental Emergencies*. 3<sup>rd</sup> ed. St. Louis, Mo: Mosby Year Book; 1995:167-212.
  27. Hubbard RW, Matthew CB, Durkot MJ, Francesconi RP. Novel approaches to the pathophysiology of heatstroke: the energy depletion model. *Ann Emerg Med*. Sep 1987;16(9):1066-75. [Medline].
  28. Khogali M, Weiner JS. Heat stroke: report on 18 cases. *Lancet*. Aug 9 1980;2(8189):276-8. [Medline].

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29. Kilbourne EM, Choi K, Jones TS, Thacker SB. Risk factors for heatstroke. A case-control study. *JAMA*. Jun 25 1982;247(24):3332-6. [Medline].
30. Kumar S. India's heat wave and rain result in massive death toll. *Lancet*. 1998;351, No. 9119.
31. Lomax P, Schonbaum E. The effects of drugs on thermoregulation during exposure to hot environments. *Prog Brain Res*. 1998;115:193-204. [Medline].
32. MMWR. Heat-related illnesses, deaths, and risk factors--Cincinnati and Dayton, Ohio, 1999, and United States, 1979-1997. *MMWR Morb Mortal Wkly Rep*. Jun 2 2000;49(21):470-3. [Medline].
33. Raju SF, Robinson GH, Bower JD. The pathogenesis of acute renal failure in heat stroke. *South Med J*. Mar 1973;66(3):330-3. [Medline].
34. Shapiro Y, Seidman DS. Field and clinical observations of exertional heat stroke patients. *Med Sci Sports Exerc*. Feb 1990;22(1):6-14. [Medline].
35. Shibolet S, Lancaster MC, Danon Y. Heat stroke: a review. *Aviat Space Environ Med*. Mar 1976;47(3):280-301. [Medline].
36. Squire DL. Heat illness. Fluid and electrolyte issues for pediatric and adolescent athletes. *Pediatr Clin North Am*. Oct 1990;37(5):1085-109. [Medline].
37. Tek D, Olshaker JS. Heat illness. *Emerg Med Clin North Am*. May 1992;10(2):299-310. [Medline].
38. Tucker LE, Stanford J, Graves B, Swetnam J, Hamburger S, Anwar A. Classical heatstroke: clinical and laboratory assessment. *South Med J*. Jan 1985;78(1):20-5. [Medline].
39. Vassalo SU, Delaney KA. Thermoregulatory principles. In: *Goldfrank's Toxicologic Emergencies*. Stamford, Conn: Appleton & Lange; 1998:285-307.
40. Vicario SJ, Okabajue R, Haltom T. Rapid cooling in classic heatstroke: effect on mortality rates. *Am J Emerg Med*. Sep 1986;4(5):394-8. [Medline].
41. White JD, Riccobene E, Nucci R, Johnson C, Butterfield AB, Kamath R. Evaporation versus iced gastric lavage treatment of heatstroke: comparative efficacy in a canine model. *Crit Care Med*. Aug 1987;15(8):748-50. [Medline].
42. Yang YL, Lin MT. Heat shock protein expression protects against cerebral ischemia and monoamine overload in rat heatstroke. *Am J Physiol*. 1999;276:H1961-H1967.
43. Yaqub B, Al Deeb S. Heat strokes: aetiopathogenesis, neurological characteristics, treatment and outcome. *J Neurol Sci*. Apr 1 1998;156(2):144-51. [Medline].
44. Yaqub BA, Al-Harhi SS, Al-Orainey IO, Laajam MA, Obeid MT. Heat stroke at the Mekkah pilgrimage: clinical characteristics and course of 30 patients. *Q J Med*. May 1986;59(229):523-30. [Medline].
45. Yarbrough B, Bradham A. Heat illness. In: *Emergency Medicine: Concepts and Clinical Practice*. 1998. 4<sup>th</sup> ed. St Louis, Mo: Mosby Year Book; 1998:986-1002.