Fire
Tech Tips

United States Department of Agriculture
Forest Service
Technology & Development Program

DRAFT

June 2010
5100 1051–2316–MTDC

Heat Illness Basics for Wildland Firefighters

Joe Domitrovich and Brian Sharkey, Project Leaders

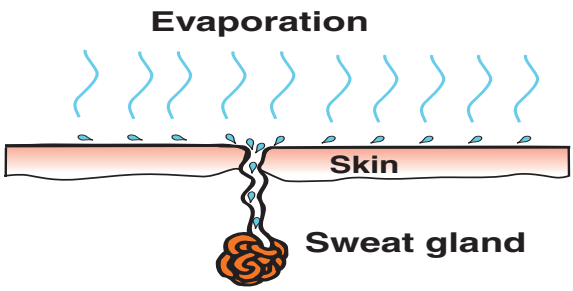
The human body can tolerate deep cold and sweltering heat so long as the body's core temperature doesn't vary much from 98.6 degrees Fahrenheit. Small changes in the body's core temperature affect cellular structures and chemical reactions. Most temperature regulating systems in the human body are designed to prevent overheating.

Muscle contractions are the body's main source of heat. When a muscle contracts during work, 75 percent of the potential energy is lost as heat. During rest, the body produces about 100 kilocalories of heat per hour, but the body can produce 10 to 15 times as much heat during exercise, depending on the exercise intensity, the size of the muscles being used, and the environmental conditions (which affect how the body loses heat).

Highlights...

- Active muscles produce most of the body's heat.
- Heat illnesses include heat cramps, heat exhaustion, and heat stroke.
- Consuming water or sports drinks does not guarantee that you won't suffer heat illnesses.
- The first step in any suspected heat illness is to have the firefighter stop working. Consuming more water or fluid will not stop the problem.

REMEMBER, sweat that drips off your body can't keep you cool. Sweat has to evaporate from your skin to cool you off.



The body's methods for preventing overheating are conduction, convection, radiation, and evaporation (sweating). When the air temperature is higher than the skin temperature, sweating is the only way to prevent overheating. During sweating, blood is diverted to the extremities, where water diffuses from the blood to the surface of the skin. As water evaporates, the body loses 580 kilocalories of heat for each liter of sweat evaporated. On average, wildland firefighters need 4 to 6 liters of water a day to stay hydrated (Ruby and others 2003). Studies have shown that firefighters drink from 200 milliliters (one fifth of a water bottle) to more than 1 liter (one water bottle) per hour over a work shift (Cuddy and others 2008, Hendrie and others 1997).

When heat gain is greater than heat loss, firefighters are at risk of suffering heat-related illnesses (figure 1).

For additional information, contact: *Joe Domitrovich, project leader; USDA Forest Service, MTDC; 5785 Hwy. 10 West; Missoula, MT 59808–9361. Phone: 406–829–6809; fax: 406–329–3719; email: jdomitrovich@fs.fed.us*

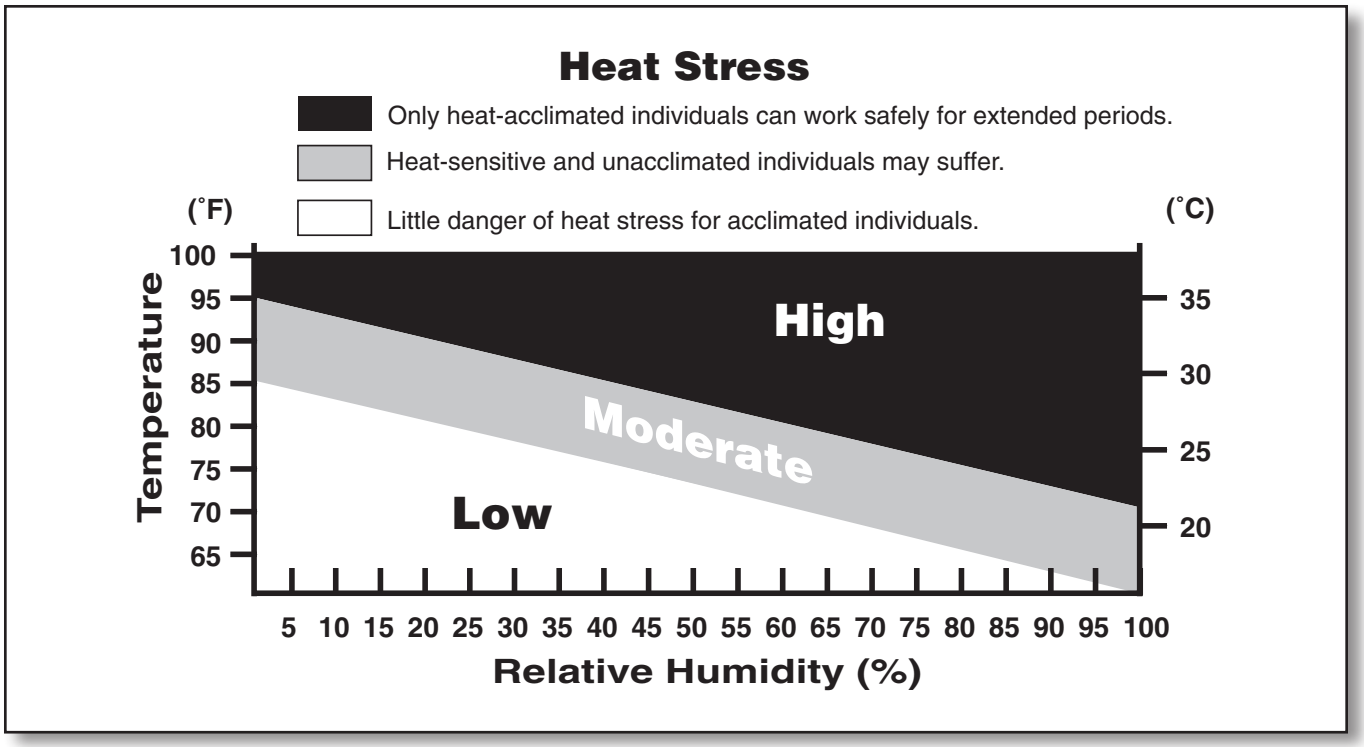


Figure 1—The risk of heat-related illness depends on temperature, relative humidity, and the work being performed. This chart is just a guide. Workers can suffer heat-related illnesses at any temperature.

Firefighters differ in their responses to heat, making heat illnesses a complex condition. The general symptoms associated with three common heat illnesses are described below, along with suggested actions firefighters can take (based on the position statements of the American College of Sports Medicine and National Athletic Trainers' Association). The descriptions also include recommendations on when firefighters can return to work safely.

Common Heat Illnesses

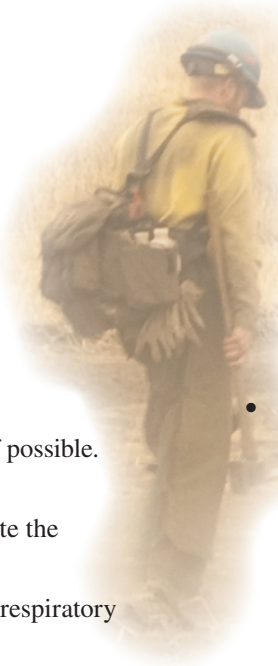
Heat Cramps can occur during or after exercise. They are the least dangerous heat illness. Heat cramps usually appear in the arms, legs, and abdominal region. Although the exact cause of heat cramps is not completely understood, cramps are thought to be caused by dehydration and/or electrolyte imbalance.

- **Signs/Symptoms**
  - ◊ Dehydration
  - ◊ Sweating
  - ◊ Muscle cramps
  - ◊ Fatigue
- **Actions**
  - ◊ Remove the firefighter from work, place in the shade if possible.
  - ◊ Rule out muscle injury.
  - ◊ Stretch the affected muscles.
  - ◊ Massage the affected muscles.
  - ◊ Check to see how much water and sports drinks the firefighter has consumed:
    If dehydration is suspected—slowly give the firefighter sports drinks with electrolytes and carbohydrates.
    If too much water is suspected—slowly give the firefighter salty foods to eat.
- **Return to Work**
  - ◊ Most firefighters will be able to return to work during the shift after they're properly hydrated and have had some time to rest.

Heat Exhaustion is the inability of the cardiovascular system to maintain adequate circulation. The firefighter cannot continue at the current work pace. During exercise or work in the heat, sweating depletes water and electrolytes, decreasing total blood volume. Firefighters suffering heat

exhaustion do not have enough blood left to transport oxygen and nutrients to their muscles.

- **Signs/Symptoms**
  - ◊ Dehydration
  - ◊ Headache
  - ◊ Profuse sweating
  - ◊ Lightheadedness/dizziness
  - ◊ Nausea
  - ◊ Cool, clammy skin
  - ◊ Fatigue/weakness
- **Actions**
  - ◊ Remove the firefighter from work.
  - ◊ Place the firefighter in the shade, if possible.
  - ◊ Loosen the firefighter's clothing.
  - ◊ Have the firefighter lie down; elevate the firefighter's legs.
  - ◊ Monitor heart rate, blood pressure, respiratory rate, and level of alertness.
  - ◊ If the firefighter can safely swallow and is not vomiting—slowly give fluids.
- **Return to Work**
  - ◊ Most firefighters with mild heat exhaustion will recover on the fireline so long as they quit working, but they should not return to work for 24 to 48 hours.
  - ◊ Firefighters with severe heat exhaustion should be seen by a physician.



Heat Stroke—the failure of the body's temperature regulating system—is life threatening. Heat stroke typically occurs when the body's core temperature is higher than 104 degrees Fahrenheit. Heat damages cells and releases cytokines (immune system secretions used in cellular communication), causing local and whole body inflammation. Organs may shut down.

- **Signs/Symptoms**
  - ◊ Irrational behavior
  - ◊ Loss of alertness
  - ◊ Loss of consciousness
  - ◊ Dehydration
  - ◊ Weakness
  - ◊ Hot and wet or dry skin
  - ◊ Tachycardia (heart rate higher than 100 beats per minute while resting)
  - ◊ Low blood pressure
  - ◊ Hyperventilation (increased respiratory rate)
  - ◊ Vomiting
  - ◊ Diarrhea
- **Actions**
  - ◊ Remove the firefighter from work.
  - ◊ Place the firefighter in the shade, if possible.
  - ◊ Loosen the firefighter's clothing.
  - ◊ Immerse the firefighter in water (in a stream or water tank), assuming you can do so safely.
  - ◊ **EVACUATE THE FIREFIGHTER IMMEDIATELY**.
- **Return to Work**
  - ◊ Based on American College of Sports Medicine (Armstrong and others 2007) and National Athletic Training Association (Brinkley and others 2002) guidelines for exertional heat illnessses, MTDC recommends the following for return to work following heat stroke.
    - ∞ No exercise for 1 week after medical release.
    - ∞ Provide a followup medical exam 1 week after the firefighter's medical release.
    - ∞ When a doctor clears the firefighter to return to work, the firefighter should begin exercising in a cool environment, waiting at least 2 weeks before heat exposure.
    - ∞ The firefighter should return to work after 2 to 4 weeks of training with no other heat-related illnesses.

Risk Factors That Can Contribute to Heat Illnesses

Hydration/Electrolyte Imbalance

- Fluid levels are critical for maintaining bodily functions. Sodium is lost in sweat. Sodium is critical in muscle and nerve functions and in maintaining water levels in the body. When loss of hydration leads to a drop of 3 to 5 percent of body weight, sweating declines. Thirst is not a good indicator of hydration. Firefighters don't become thirsty until they have lost 700 milliliters of fluid or about 1 percent of body weight. Studies have shown that most individuals drink enough to replace just half of the water they lose in sweat; this has been termed "voluntary dehydration" (Adolph 1947). Dehydration is not required for heat illnesses. Over a 22-year period, the military reported that only about 17 percent of all soldiers suffering heat-related illnesses were dehydrated (Pandolf and others 1988).

- To avoid dehydration, monitor your hydration status before, during, and after the work shift by monitoring your urine color. Urine should be a "wheat" color. If your urine is clear, you have consumed too much water and your body is trying to get rid of the excess. If your urine is dark, you have not consumed enough water (you are dehydrated) and your body is holding onto as much water as it can. Remember to consume fluids before, during, and after the work shift.
- Consuming too much water can create as many problems as failing to consume enough.
- Caffeine
  - ◊ The consumption of caffeine in sports has been discouraged because caffeine is a mild diuretic and may increase the likelihood of heat illnesses. However, recent research has shown that moderate consumption of caffeine (four 8-ounce cups of coffee for a 150-pound firefighter) does not harm hydration or increase the likelihood of heat illnesses (Lopez and Casa 2009).
  - ◊ From one-third to one-half of the fluid you consume should be sports drinks. The sports drink can be in a separate beverage, or you can mix a sports drink package into a water bottle. Sports drinks can help you maintain your electrolyte balance and give you energy in the form of carbohydrates.

For more information about sports drinks, see "Wildland Firefighter Health and Safety Report: No. 8" (Sharkey 2004).

Overexertion can lead to rhabdomyolysis, when muscle cells break down and their contents are released into the blood. At high levels, the contents of muscle cells can be toxic to the kidneys. If firefighters' muscles are overheating, they are more subject to the risk of rhabdomyolysis.

Illness/Fatigue

- Illness can contribute to dehydration. Vomiting and diarrhea quickly dehydrate a firefighter. A respiratory infection or viral illness can cause a fever, raising the body's core temperature. Skin-related injuries (such as sunburn) can reduce the body's ability to sweat. Genetic diseases (sickle cell) can reduce blood supply to tissues and organs, making it more difficult for the body to cool itself.
- It is important to remain healthy during the fire season. Make sure to wash your hands frequently. Do not share personal items with other firefighters. If you do become ill, let a crewmember or squad leader know.
- Sleep loss has been linked to some loss of heat tolerance, possibly because less blood flows to the extremities and the body produces less sweat.
- It is important to get more than 4 hours of sleep per night, ideally at least 8 hours. Getting enough sleep can be difficult during assignments, but if you have the opportunity for extra rest, take it.

Physical Conditioning

- Firefighters who are physically fit will work harder and at a higher percentage of their maximal capacity. Physical fitness training also increases blood volume and dilutes sweat, reducing the amount of electrolytes lost. Nonetheless, sweat rates and electrolyte loss vary from person to person.

Lack of Acclimation

- Acclimation is your body's adaptation to a different environment. Heat acclimation usually takes 2 weeks, but improvements begin appearing after 4 or 5 days. Acclimation to heat includes increased sweating at a lower temperature, sweat that is not as salty (saving electrolytes), and an increase in blood volume. The body starts to cool itself earlier and does a better job of transferring heat from the body's core to the skin and to the environment. Increased blood volume means there is more blood to help control the body's temperature and deliver energy to the muscles.

Firefighters' Clothing

- Clothing needs to protect wildland firefighters from environmental conditions (tree branches, heat) while allowing body heat to escape. Clothing that provides more protection from the environment is less able to dissipate body heat.
- Undergarments should be loose fitting to allow moisture to evaporate from the skin. Modern athletic clothing relies heavily on synthetic materials but, the MTDC Tech Tip "Tests of Undergarments Exposed to Fire" showed that 100-percent natural fiber undergarments are less likely to burn (Petrilli and Ackerman 2008).

Medication/Drugs

- Some medications that may contribute to heat illnesses include beta blockers, antihistamines, and antidepressants. Drugs such as amphetamines, cocaine, cannabinoids (such as marijuana), and alcohol also can contribute to heat illnesses.
- Check with your doctor or pharmacist to determine whether any of your medications can contribute to heat illnesses.

MTDC Recommendations

- If you suspect a heat illness, remove the firefighter from work. The key for treatment is to remove the main source of heat—muscle contractions. Working too hard can produce heat illness, regardless of the environment.
- Have crewmembers use the buddy system, where buddies are alert for small changes in performance or behavior of fellow crewmembers who might not notice the changes in themselves.
- When you're taking fire weather observations, refer to the chart in figure 1 so you can alert firefighters when heat illnesses are most likely.
- When you are assigned to a new environment, pay extra attention to the possibility of heat illnesses. You may need to adjust work intensity or work schedules. This is also true for early season locations that may be in hotter, drier environments than your home unit.
- Maintain fitness levels throughout the season, especially at the beginning of the season. Do not increase the level of exertion too quickly during the early season.
- Consume fluids regularly before, during, and after the work shift. Drink about one-fourth to one water bottle of fluid per hour during the work shift, depending on the work intensity and environmental conditions. About one-third to one-half of the fluid should be sports drinks.

Selected References

Adolph, E. F. 1947. Physiology of man in the desert. Interscience.

Armstrong, Lawrence E. 2000. Performing in extreme environments. Champaign, IL: Human Kinetics. 344 p.

Armstrong, Lawrence E; [and others]. 2007. Exertional heat illness during training and competition. Medicine & Science in Sports & Exercise. 39(3): 566-572.

Binkley H. M.; [and others]. 2002. National athletic trainers position statement: exertional heat illness. Journal of Athletic Training. 37(3): 329-343.

Cuddy, John S.; Ham, Julie A.; Harger, Stephanie G.; [and others]. 2008. Effects of an electrolyte additive on hydration and drinking behavior during wildfire suppression. Wilderness and Environmental Medicine. 19(3): 172-180.

Hendrie, A. L.; Brotherhood, J. R.; Budd, G. M.; [and others]. 1997. Project aquarius 8. Sweating, drinking, and dehydration in men suppressing wildland fires. International Journal of Wildland Fire. 7(2): 145-158.

Lopez, Rebecca M.; Casa, Douglas J. 2009. The influence of nutritional ergogenic aids on exercise heat tolerance and hydration status. Current Sports Medicine Reports. 8(4): 192-199.

Pandolf, Kent B.; Sawka, Michael N.; Gonzalez, Richard R. 1988. Human performance physiology and environmental medicine at terrestrial extremes. Traverse City, MI: Cooper Publishing Group. 637 p.

Petrilli, Tony; Ackerman, Mark. 2008. Tests of undergarments exposed to fire. Tech Tip 0851–2348–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 10 p.

Ruby, Brent C.; Scholler, Dale A.; Sharkey, Brian J.; [and others]. 2003. Water turnover and changes in body composition during arduous wildfire suppression. Medicine & Science in Sports & Exercise. 35(10): 1760-1765.

Sharkey, Brian. 2004. Wildland firefighter health and safety report: No. 8. Tech Rep. 0451–2802–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 12 p.

About the Authors

Joe Domitrovich is an exercise physiologist at MTDC. His work includes hydration, nutrition, employee health, stress, and fitness testing. Domitrovich also is a wildland firefighter. He received a bachelor's degree in kinesiology at Cal Poly San Luis Obispo in California and a master's degree in exercise physiology at the University of Montana, where he is completing an interdisciplinary studies Ph.D. with an emphasis in exercise science.

Brian Sharkey, an exercise physiologist at MTDC, has done research and development work on fitness tests and programs, heat stress, hydration, nutrition, protective clothing, tools, fatigue, work/rest cycles, and employee health (wellness). His work has been honored with USDA Superior Service and Distinguished Service Awards, a Forest Service Technology Transfer Award, and the International Association of Wildland Fire Safety Award. He is past president of the American College of Sports Medicine and author of several books including "Hard Work," 2008, with Dr. Paul Davis, published by Human Kinetics.

Library Card

Domitrovich, Joe; Sharkey, Brian. 2010. Heat illness basics for wildland firefighters. Tech Tip 1051–2316–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 8 p.

Wildland firefighters, who put in long hours of hard work in the heat, are subject to heat illnesses, including heat cramps, heat exhaustion, and heat stroke. This tech tip offers advice that will help wildland firefighters prevent heat illness, recognize the signs of heat illness, and know what to do in the event of heat illness. The first step to take when heat illness is suspected is to remove the victim from work.

Keywords: acclimation, acclimatization, clothing, cramps, fitness, heat exhaustion, heat stroke, hydration, medications, safety at work, symptoms, temperature

Additional single copies of this document may be ordered from:

USDA Forest Service
Missoula Technology and Development Center
5785 Hwy. 10 West
Missoula, MT 59808–9361
Phone: 406–329–3978
Fax: 406–329–3719
E-mail: wo_mtdc_pubs@fs.fed.us

Electronic copies of MTDC's documents are available on the Internet at:

http://www.fs.fed.us/eng/t-d.php

For additional information about heat illness, contact Joe Domitrovich at MTDC:

Phone: 406–829–6809
Fax: 406–329–3719
Email: jdomitrovich@fs.fed.us

Forest Service and Bureau of Land Management employees can search a more complete collection of MTDC's documents, CDs, DVDs, and videos on their internal computer networks at:

http://fsweb.mtdc.wo.fs.fed.us/search/