

# HEAT ILLNESS AWARENESS AND PREVENTION

BY ICRI COMMITTEE 120, ENVIRONMENTAL HEALTH AND SAFETY, AND KELSEY ROMAO

According to the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) data, 230 heat-related deaths have occurred from 2003-2009 with 81 (40%) of these fatalities occurring in the construction industry. Over that same time period, 15,370 heat-related injuries/illnesses requiring days away from work have occurred with 4110 (27%) of these injuries/illnesses in the construction industry.<sup>1</sup> Heat-related fatalities are not limited to southern climates but may occur anywhere in the United States (Fig. 1).<sup>2</sup> What measures can employers take to prevent on-the-job heat-related injuries?

## WHAT ARE HEAT ILLNESSES?

Heat illnesses, which can lead to heat-related injuries, are broken down into two stages: heat

exhaustion and heatstroke (Fig. 2).<sup>3</sup> “Heat exhaustion is characterized by muscle cramps, fatigue, headache, nausea or vomiting, and dizziness or fainting. The skin is often cool and moist, indicating that the body’s mechanism for cooling itself (that is, sweating) is still functioning. The pulse rate is typically fast and weak, and breathing is rapid and shallow. If untreated, heat exhaustion can progress to heatstroke. Heatstroke is a serious, life-threatening condition characterized by a high body temperature (>103°F [ $>39.4^{\circ}\text{C}$ ]); red, hot, and dry skin (no sweating); rapid, strong pulse; throbbing headache; dizziness; nausea; confusion; and unconsciousness. Symptoms can progress to encephalopathy, liver and kidney failure, coagulopathy, and multiple system organ dysfunction. Prompt treatment of heat-related illnesses with aggressive fluid replacement and cooling of core body temperature is critical to reducing morbidity and mortality.”<sup>4</sup>

## THE BIOLOGY OF THERMOREGULATION

Before determining how we can prevent heat illnesses, it is important to develop a basic understanding of how the body regulates heat. All these functions are performed by the brain’s hypothalamus, located just above the brain stem. While the human hypothalamus is approximately the size of an almond, it controls important vital functions, including not only thermoregulation but also hunger, thirst, fatigue, sleep, and circadian cycles. There are two parts of the hypothalamus, with each serving a different function in the heat regulation process. The anterior serves as a “thermostat” and the posterior provides a “set-point” for the core temperature and initiates physical responses. When the body exceeds its typical “set-point” temperature, it puts into motion mechanisms for self-regulation. The first instructions from the hypothalamus are given to the nervous system to increase surface skin blood flow. This helps to dissipate some of the body’s heat by moving blood away from the body’s core. If necessary, a second instruction is sent from the hypothalamus to begin sweating. Sweat is comprised of three main components: water, sodium chloride (salt), and potassium. The body is cooled when sweat evaporates from the surface of the skin.<sup>5</sup>

The human body is capable of generating 1 qt. (1 L) of sweat per hour, with each quart (liter)

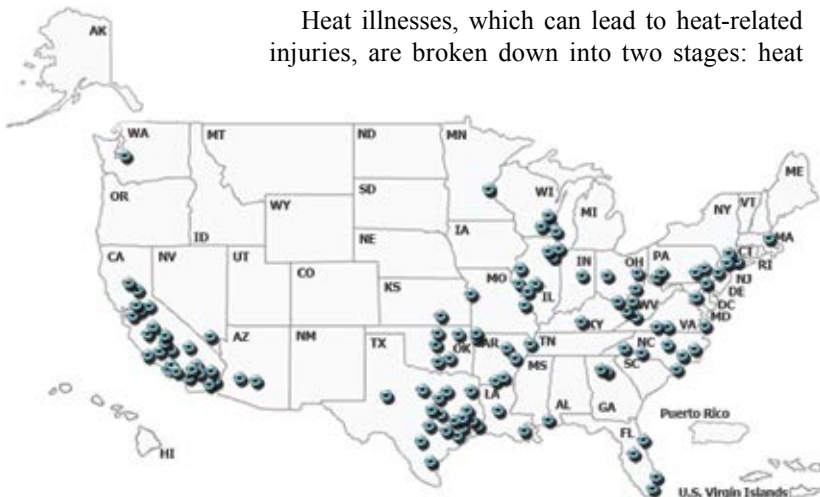


Fig. 1: Heat-related fatalities between 2008 and 2013<sup>2</sup>

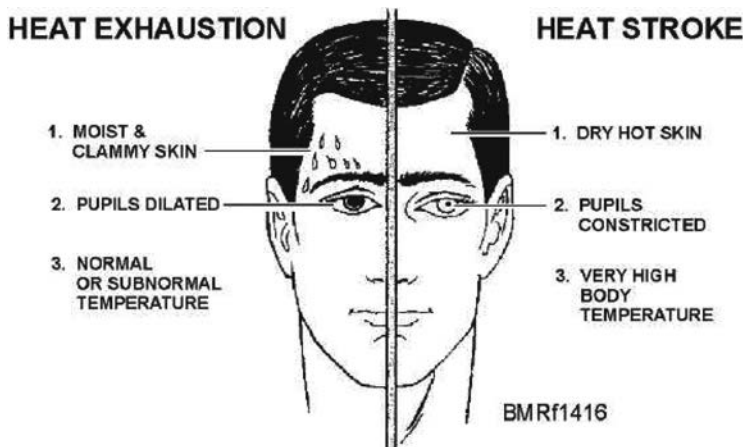


Fig. 2: Heat exhaustion versus heatstroke<sup>3</sup>



Fig. 3: Fluids must be replenished while sweating

representing a loss of 580 kcal (2430 kJ) of heat to the environment. “The rate of evaporation of sweat is controlled by the difference in the water vapor pressure on the sweat-wetted skin surface and the air layer next to the skin, and by the velocity of air movement over the skin. As a consequence, hot environments with increasing humidity limit the amount of sweat that can be evaporated.”<sup>5</sup> If sweat cannot evaporate, it simply drips from the skin’s surface and plays no role in cooling the body. Essentially, dripping sweat simply represents a futile loss of water, salt, and potassium from the individual’s body.

During high fluid output as a result of sweating, it is imperative that the fluids are replaced in the body (Fig. 3). While it is possible that a deficiency in sodium chloride and potassium could occur, this is not typical. In fact, in most cases, it is only necessary to replenish water levels to keep the system working appropriately. Given the average American’s salt intake—even for those monitoring their salt levels due to high blood pressure—increasing one’s salt consumption to replenish what is lost from sweating is not warranted. Likewise, potassium is found in most foods—especially meats and fruits—and generally does not necessitate supplementation, except for individuals taking diuretics.<sup>5</sup>

If the water losses are not replenished, however, individuals will become dehydrated. Dehydration reduces the evaporative and convective heat loss, increases cardiovascular strain, and increases the possibility of heat-related injury. Consequently, dehydrated workers will have reduced physical work capabilities and their mental performance will often degrade, especially during monotonous and repetitive tasks. If the body’s thermoregulation mechanisms are unable to combat the excess heat and reduce the body’s core temperature, the initial onset of heat exhaustion may occur.

## ADAPTATIONS

Humans will biologically adapt to heat stress in two ways. Heat acclimatization occurs when the body’s response to heat improves after a few days of regular strenuous work and heat exposure.

The heat-acclimatized body can have a core temperature reduction of  $-2^{\circ}\text{F}$  ( $1^{\circ}\text{C}$ ) and a heart rate 40 beats per minute less than it did when performing work on the first day of work with high heat exposure. Some of the physical adaptations will “include improved sweating, better fluid balance, improved cardiovascular stability, and lowered metabolic rate.”<sup>6</sup>

Similarly, after multiple days of work and heat exposure, the body’s cells will adapt to allow tissues and organs to become more resistant to heat; this is called acquired thermal tolerance. This allows an individual to become more resistant to heat illness with subsequently more severe heat exposures. Individuals without recent heat exposure are at a higher risk for heat illness. It is especially important to monitor the fluid intake and work-rest cycles of these individuals during the first days of exposure while the body acclimates to the new risk factors.

## PREVENTION

The risk factors that should be considered when addressing heat stress are not only environmental factors but also individual and site-specific risks. While many people associate heat stress with work performed outdoors during hot and humid summer days, it is also important to be aware of heat stress caused by hot indoor environments, such as boiler rooms, heated tanks, power plants, and welding shops. Such environments can be inclement due to their temperature, humidity, wind, and solar loads. In addition to environmental factors, some site-specific factors that could lead to heat stress include work intensity, duration of heat exposure, and equipment worn. Likewise, individual factors that could affect heat stress include the physical fitness and overall health of the worker, their heat acclimatization status, use of medications, and alcohol and drug abuse.

Successful management of heat stress depends on the education of the field leaders and crews exposed to heat. Procedures must be in place to alert the crews of dangerous heat-stress levels. “Measures to prevent heat illness include environmental monitoring, engineering controls, acclimatizing workers, frequent intake of water, work practices, training, and medical screening.”<sup>7</sup>

**Environmental Monitoring:** Generally, there are two ways to consistently monitor the environment. One commonly used screening criterion is wet-bulb globe temperature (WBGT). The WBGT is a composite temperature that accounts for ambient temperature, air movement, humidity, and radiant heat load. The WBGT can be used as a guide for determining the work-rest frequency. “The internationally accepted standard that provides a simple method for the assessment and control of hot environments is ISO 7243, ‘Hot Environments

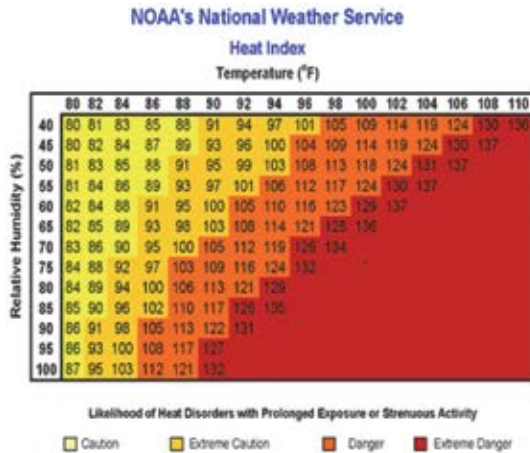


Fig. 4: NOAA's heat index exposure chart<sup>9</sup>

Estimation of the Heat Stress on Working Man, Based on the WBGT Index.”<sup>8</sup> Another widely used criterion is heat index, which is calculated and provided by the National Weather Service (Fig. 4)<sup>9</sup> and many news and weather stations. While commonly used, it is important to recognize that the heat index value does not account for air movement, radiant heat, or the effect of personal protective equipment (PPE).

**Clothing/Equipment:** Appropriate clothing should be worn to protect workers against exposure to wind and radiation from the sun. Covering the skin with lightweight fabrics such as cotton can help to keep skin cool and protected. Sunscreen should be applied to exposed areas of the skin to avoid sunburn; even mild sunburn can affect the body's ability to sweat.

In 2009, the American Society of Petroleum Engineers (ASPE) used the WBGT to analyze the effects of colored PPE on heat-stress loads. The published study measured heat-stress loads of colored hard hats—notably dark blue—versus white hard hats. The testing concluded that the surface temperature of dark blue hard hats was as much as 49°F (27°C) higher, radiant heat was 5°F (3°C) higher, and the individuals wearing blue hard hats evaporated up to 60% more water than individuals wearing white hard hats during the test cycle. The ASPE concluded that colored hard hats made a significant difference in the surface temperature of the hard hat, thereby affecting air temperature and heat radiation beneath the hard hat and the ability of the body to dissipate heat through the head. This data confirms that significantly higher heat-stress loads are endured by workers wearing blue hard hats as opposed to white.<sup>10</sup>

**Engineering Controls:** These can provide much relief to workers in severe conditions. Providing cool, dry air to a work area can significantly reduce heat-stress loads on the body. Likewise, mist can be used to cool workers directly, when possible. In industrial settings, insulation and shields can be

used to protect workers from heat radiating from the surfaces of heavy equipment. Air-cooled garments can be worn to help facilitate the evaporation of sweat in an effort to cool the body. Shade structures can be provided to the job site, particularly when the temperature exceeds 85°F (29°C).

**Acclimatization:** Workers' exposure to heat stress should be gradually increased over time. New workers, or workers returning from a 2-week absence or more, should have a 5-day acclimatization period of progressive heat exposure and physical work. Assuming an 8-hour workday, the new employee should be given 50% of the typical workload and an exposure time of no more than 4 hours. In the days to follow, the workload and exposure time is increased incrementally until reaching 100% on the fifth day.<sup>7</sup>

“On repeated exposure there is a marked adaptation in which the principle physiologic benefit appears to result from an increased sweating efficiency (earlier onset, greater sweat production, and lower electrolyte concentration) and a concomitant stabilization of the circulation, so that after daily heat exposure for 7 to 10 days, the individuals perform the work with a much lower core temperature and heart rate and a higher sweat rate (i.e., a reduced thermoregulatory strain) and with none of the distressing symptoms that were experienced at first.”<sup>5</sup>

By the end of the first week, 50% of the physiologic adaptations are complete; by the end of the second week, that percentage is 80%. Once heat exposure is stopped, the benefits from adaptation will remain for up to 1 week, and decline approximately 25% per week thereafter.<sup>6</sup>

**Frequency of Fluid Intake:** Workers should be fully hydrated before the start of any work period, and should be encouraged to drink small amounts of cool liquids—except beverages with alcohol or high caffeine levels—every 20 minutes or so. Workers will tend to ingest more water if it is made more palatable by means of cooling or by lightly flavoring it with citrus fruit flavors. If workers wait until thirst sets in before they consume liquids, fluid replacement will lag behind sweat losses for several hours. Workers should also consume fluid during mealtime because food will help to retain water in the body longer.

**Work Practices:** These can help to alleviate heat stresses on the body, such as reducing the physical demands of work, scheduling work during cooler parts of the day (that is, night work), and using intermittent rest periods. WBGT can be used to determine the appropriate work-rest cycles as discussed previously. In addition, a “buddy system” can be effective when rest breaks in cool areas are not possible. The system pairs workers together so that atypical behavior that is caused by



heat stress can be observed by another person and treated quickly.

**Employer-Monitoring Practices:** These may be used to minimize heat stress, such as monitoring workers' pulse rates, oral temperature, and body water loss. For example, the work period may need to be shortened if:<sup>11</sup>

1. The heart rate taken as early as possible after rest begins exceeds 110 beats per minute;
2. The oral temperature exceeds 99.6°F (37.6°C); or
3. The weight lost during the work exceeds 1.5% of a worker's body weight.<sup>11</sup>

Self-monitoring of urine color and volume can also help to assess a worker's hydration status. Urine that is dark in color and low in volume indicates dehydration and requires an increase in fluid consumption.<sup>6</sup>

**Medical Screenings:** These can be used to identify workers with preexisting medical conditions; high blood pressure; and the use of certain prescription drugs, which may elevate their risks of heat illness.

## MANAGEMENT OF HEAT-STRESS SYMPTOMS

**Signals/Symptoms:** Prompt management of heat-stress symptoms is crucial to avoiding heat illness. Workers must familiarize themselves with the symptoms of heat stress so they can seek help when necessary. Some of the most common warning signs and symptoms are dizziness, headache, nausea, unsteady walk, muscle weakness and cramping, fatigue, and chills. Serious signals/symptoms where immediate medical response may be necessary include high core temperature, confusion/disorientation, vomiting, involuntary bowel movement, convulsions, weak or rapid pulse, agitation, and unresponsiveness/comatose.

**Cooling:** Generally, most common symptoms will warrant removal from work activity, rest in shade or a cooler environment, loosening of clothing, ingestion of more fluids, and further evaluation for other more serious symptoms. In the case of more serious symptoms where a medical response or ambulance is needed, the person should be laid down in a cool environment or shade with feet elevated and any unnecessary garments removed. Ice packs can be placed over major arteries in the head, neck, groin, and armpit regions or cool water poured over the body. If water is poured over the body, fanning can accelerate cooling by evaporation. Cooling can also be achieved by applying cool, wet cloths loosely around the neck and to the surface of uncovered skin. Conscious persons can be given sips of water, but if unconscious, persons should be laid on his/her side with the airway closely monitored to prevent the aspiration of vomit.

**Rehydration:** For moderate dehydration, oral intake of fluids is just as effective as intravenous infusion. Water is typically used for rehydration, but for workers with higher levels of dehydration, sports drinks can potentially be more effective due to their infusion of sodium, glucose, and electrolytes.

The severity of the heat illness is not always apparent when first noticed in the field. Field leaders must initiate cooling and rehydration of workers suspected of having potential heat illness as quickly as possible. The biggest factor increasing the survivability and prevention of a serious heat-related injury is early initiation of cooling and rehydration. By addressing the symptoms early, heat-stressed patients demonstrate rapid improvement within the first hour. It is better to provide treatment even when uncertainty is present.

## CONCLUSIONS

How can we start to use this information to prevent heat-related injuries among employees in our industry? Many organizations have tasked themselves with answering this question and have provided information sheets, bulletins, and guidelines on the subject. For example, OSHA offers a variety of publications, job-site posters, and business cards to emphasize the dangers of heat stress (Fig. 5).<sup>12</sup> CAL/OSHA suggests that a written procedure be created and that all jobs should be evaluated for conditions contributing to heat illness:

1. "Identify the designated person(s) that has been assigned the applicable task(s) (e.g. supervisor, foreman, safety coordinator, crew leader);
2. Provide specific details required to carry out the task and ensure that the task is accomplished successfully (e.g. how many water containers/shade structures, of what size, distance to placement, frequency of water-level replenishment/weather-tracking/water breaks/reminders, etc.); and



Fig. 5: OSHA offers a variety of heat awareness posters<sup>12</sup>

3. Specify how these procedures will be communicated to your employees and in particular to the persons assigned these responsibilities (e.g. via training, meeting), and how it will be ascertained that these company instructions and procedures are followed.”<sup>13</sup>

As part of any job-specific safety plan, a designated person should identify job-specific heat-related hazards and prevention. This person should consider and evaluate items such as crew size, length of work shift, ambient temperature, and PPE, and should adjust the areas that can be improved.

CAL/OSHA recommends that procedures be in place for the following items and situations on all job sites: provision of water, access to shade, monitoring of weather, handling a heat wave, high-heat procedures, acclimatization, emergency response system, sick employees, and supervisory training.<sup>13</sup> The use of a heat-stress safety checklist will provide a guide to help determine the potential for heat stress in the work place.<sup>14</sup>

While this is a limited representation of measures that can be taken, it helps to illustrate the opportunities that exist to improve the effectiveness of a company’s current program in combating heat stress and illness and heat-related injuries.

## REFERENCES

1. Occupational Safety and Health Administration (OSHA), 2011, “U. S. Labor Department Aims to Protect Workers from Heat-related Illnesses,” The Associated General Contractors of America (AGC), <http://news.agc.org/2011/05/05/u-s-labor-department-aims-to-protect-workers-from-heat-related-illnesses>. (last accessed Mar. 6, 2014)
2. Occupational Safety & Health Administration (OSHA), 2013, “Heat Fatalities [Map],” OSHA.gov, <https://www.osha.gov/SLTC/heatillness/map.html>. (last accessed Apr. 2, 2014)
3. Integrated Publishing, Inc., 2013, “Heatstroke,” [www.tpub.com](http://www.tpub.com), [http://navyadvancement.tpub.com/14325/css/14325\\_407.htm](http://navyadvancement.tpub.com/14325/css/14325_407.htm). (last accessed Apr. 2, 2014)
4. Centers for Disease Control and Prevention (CDC), 2006, “Heat-Related Deaths—United States, 1999-2003,” *MMWR Weekly* 55(29); 796-798, <http://cdc.gov/mmwr/preview/mmwrhtml/mm5529a2.htm>. (last accessed Mar. 6, 2014)
5. National Institute for Occupational Safety and Health (NIOSH), 1986, “Criteria for a Recommended Standard...

Occupational Exposure to Hot Environments,” Centers for Disease Control (CDC), <http://www.cdc.gov/niosh/docs/86-113/86-113.pdf>. (last accessed Mar. 7, 2014)

6. Sawka, M. N.; Wenger, C. B.; Montain, S. J.; Kolka, M. A.; Bettencourt, B.; Flinn, S.; Gardner, J.; Matthew, W. T.; Lovell, M.; and Scott, C., 2003, “Heat Stress Control and Heat Casualty Management (TB MED 507),” U.S. Army Research Institute of Environmental Medicine, Technical Bulletin TB MED 507/AFPAM 48-152 (I), [http://armypubs.army.mil/med/dr\\_pubs/dr\\_a/pdf/tbmed507.pdf](http://armypubs.army.mil/med/dr_pubs/dr_a/pdf/tbmed507.pdf). (last accessed Mar. 7, 2014)

7. Congressional Accountability Office of Compliance, 2009, “Fast Facts: Heat Stress,” Office of Compliance, [http://www.compliance.gov/wp-content/uploads/2010/03/fastfacts\\_heatstress.pdf](http://www.compliance.gov/wp-content/uploads/2010/03/fastfacts_heatstress.pdf). (last accessed Mar. 6, 2014)

8. Bellingier, T., 2009, “Wet Bulb Globe Temperature Measurement at the Y-12 National Security Complex,” Department of Energy, <http://orise.orau.gov/emi/dmcc/files/WBGT%20Bellingier.pdf>. (last accessed Mar. 7, 2014)

9. National Weather Service, 2014, “National Weather Service Heat Index,” <http://www.nws.noaa.gov/os/heat/images/heatindex.png>. (last accessed Apr. 2, 2014)

10. Davis, M.; Kaminski, D.; Oliver, M. C.; Graf, J.; and Pilling, L., 2009, “A Study of Heat Related Factors Caused by Color Selection of Hard Hats and FRC Garments in Out Door Work Environments,” Society of Petroleum Engineers, ISBN 978-1-55563-263-2, Conference Presentation 2009 SPE Annual Technical Conference and Exhibition, New Orleans, LA, pp 1-7.

11. Occupational Safety & Health Administration (OSHA), 2013, “Monitoring Workers at Risk of Heat-related Illness,” OSHA.gov, [https://www.osha.gov/SLTC/heatillness/heat\\_index/monitoring\\_workers.html](https://www.osha.gov/SLTC/heatillness/heat_index/monitoring_workers.html). (last accessed Mar. 7, 2014)

12. Occupational Safety & Health Administration (OSHA), 2013, “Educational Resources: Fact Sheets/Posters/Training Material,” OSHA.gov, <https://www.osha.gov/SLTC/heatillness/edresources.html>. (last accessed Apr. 2, 2014)

13. State of California Department of Industrial Relations (CAL/OSHA), 2011, “Employer Sample Procedures for Heat Illness Prevention,” [http://www.dir.ca.gov/dosh/dosh\\_publications/ESPPIP.pdf](http://www.dir.ca.gov/dosh/dosh_publications/ESPPIP.pdf). (last accessed Mar. 6, 2014)

14. UCLA-Labor Occupational Safety and Health Program, 2006, “Heat Stress Safety Checklist,” UCLA-LOSH, <http://www.losh.ucla.edu/losh/resources-publications/fact-sheets/heat%20stress/Heat-Stress-Checklist.pdf>. (last accessed Mar. 7, 2014)

---

**ICRI Committee 120, Environmental Health and Safety:** Don Caple, Chair; Rusty Boicourt; William Brickley; Charles Brienza; David Caple; Scott Greenhaus; Kevin Michols; Beth Newbold; and Pat Winkler.