Don't Sweat It!

Heat Injuries and Fluid Management in the SCA

Galen of Ockham

July, AS XXXII (1997) with updates July AS XXXIV (1999)

The major concerns working with Fighters during the warmer months are helping them keep safe from heat injuries and keeping them well hydrated. This missive will discuss how to keep your cool despite the heat.

Heat Transfer

Let's begin by looking at how heat is transferred between the body and the environment. Knowing how heat is transferred will give some insight into how these mechanisms can affect the fighter.

There are four basic mechanisms of heat transfer: conduction, convection, radiation, and evaporation.

Conduction

Conduction is the transfer of heat by direct contact with a solid. A fighter who is 'dead' and lying on a blacktop surface will gain much more heat than one lying on grass. This is also a way that people who indulge a bit much, pass out, and lay on the cool ground for prolonged periods of time lose a significant amount of body heat.

The amount of heat lost or gained by conduction depends on the temperature of the surface, how much of the body is in direct contact, and how much insulation (e.g., clothing, armor) is between the person and the surface.

Convection

Convection is the transfer of heat by direct contact with moving fluids, most commonly the air (yes, air is indeed considered a fluid - at least by your local physicist). Your body heats up the

air immediately around it (assuming the air temperature is less than body temperature, which is not always the case!). This warm air surrounding the body then forms an insulating boundary layer. However, if there is a wind blowing, it can disrupt this boundary layer and allow fresh, cooler air to come in contact with the body. By disrupting this insulating layer of air, the body can be cooled. We naturally seek convective cooling by trying to stand where a breeze is blowing or in front of a fan.

Clothing interferes with convection since it does not allow the moving air to come into contact with the body.

Radiation

Radiation is the direct transfer of heat energy by infrared energy. It does not require a medium such as air or water. We experience radiative heating anytime we stand in the sun, and avoid it by seeking a shady spot to rest.

Darker colored clothing or materials will absorb more of this energy and will therefore make you feel hotter in the sun than if you were wearing lighter colored clothing.

Evaporation

Evaporation is the most efficient and important mechanism for cooling the body, especially in warm environments. It works by taking heat energy from the body and using it to convert water to water vapor, i.e. evaporating it. This is why the body goes to so much trouble to generate large quantities of sweat. Evaporation also works with water sprayed on the skin (however, if quantities of water are limited, you are much better putting it *in* the body rather than *on* it). High relative humidity is the enemy of evaporation. If the air already contains as much moisture as it can (a relative humidity of 100%), then water will be unable to evaporate. A breeze to bring fresh, drier air will also aid evaporative cooling as the air surrounding the body will become saturated with moisture (very similar to the warm air boundary layer discussed under convection). Clothing that keeps out air will also decrease the efficiency of evaporation.

How does all this affect the fighter?

Fighters have several factors working against them to increase their heat production and prevent efficient cooling.

Armor

Armor acts as an insulator that prevents conductive and radiative heat loss. It also tends to keep out the breeze, which decreases conductive and evaporative heat loss. If the color of the armor is dark, it can gain heat by radiative heating, especially in an unshaded field. Even highly polished stainless steel will heat up in direct sunlight. The helm will prevent heat loss from the head (yes, Mom was right when she told you to put on a hat in winter!). The extra weight of the armor will increase workload, and therefore, the body's heat production from the extra work.

Fighting

Fighting is exercise, and will greatly increase the amount of heat produced by muscular activity. SCA fighting can resemble anything from sprinting (list with a quick kill) up to a marathon (melee with resurrection).

How about the non-fighter?

The good gentles on the sidelines are also susceptible to the effects of the heat. Heavy garb, dark colors, inadequate hydration (and active dehydration by drinking only alcohol or caffeinated drinks) on their part will put them at risk. Therefore don't forget to keep your eyes on the crowd as well as the lists. Use the "weak link" concept – the first patient you see with a heat-related problem is probably only the tip of the iceberg. Aggressively monitor (and water) the populace.

Other Factors

In addition to interfering with the physics of heat transfer, we can have a full armamentarium of methods of worsening our resistance to the heat. The factor we have the most control over is our own hydration level. A dehydrated body is less efficient at cooling. Improper diet, hot and humid environments, inadequate rest, and anxiety can all decrease a gentle's ability to tolerate the heat. If you spend all week in an air conditioned office and drive to work from your air conditioned home in your air conditioned car, you are probably not acclimated to the heat. It takes anywhere from 2 – 6 hours per day of mild to moderate exercise in the climate for 2 – 3 weeks to become acclimated to the heat.

Heat Injuries

An article on the heat would not be complete without discussing the three main types of heat injury.

Heat cramps

Heat cramps is a mild form of heat illness manifest by cramps in the muscles that are being vigorously exercised, typically the legs or abdomen. They are most common following vigorous exercise. They do not seem to be due to any gross changes in the serum electrolytes, but more of a result of local changes in the electrolytes in the muscles. Though annoying and sometimes quite painful, they are not dangerous by themselves. It is, however, a sign that more serious heat injuries may be on the way.

Treatment includes rest and rehydration.

Prevention is proper hydration, diet, and physical conditioning prior to exercise.

Heat exhaustion

Heat exhaustion is the most frequent heat-related illness. It is characterized by weakness, dizziness, profound sweating, nausea, vomiting, headache, muscle cramps, and fainting. The patient may have an ashen appearance, be diaphoretic (sweaty), tachycardic (high heart rate), and/or have a slight (if any) elevation of body temperature.

Treatment is stop exertion, get the patient to a cool area, loosen clothing (as modesty allows), and rehydrate. If nausea is severe or the person is otherwise unable to take in fluids, IV rehydration may be necessary.

Prevention is proper conditioning and heat acclimatization, adjusting activity to suit environmental conditions, and adequate hydration and diet.

Heat stroke

Heat stroke is a life-threatening, true medical emergency. The body temperature may reach 106^{o}F or higher. There will be CNS (central nervous system) disturbances such as stupor, seizures, or coma. There will probably *not* be absence of sweating. Heat stroke can be brought on by ignoring the signs of heat exhaustion and continuing exertion or it can come on suddenly. The type of heat stroke seen in athletes typically is the sudden

onset variety and is likely to occur while the patient is still sweating. The description of heat stroke that is typically found in pre-hospital emergency books describes a patient with hot, red, dry skin and an absence of sweating. This classic picture is what one would find if the body temperature increases slowly over a matter of hours to days. We read about this type of death all too frequently during summer heat waves when elderly people who can't afford air conditioning are found dead in their apartments. The fighter, however, becomes hyperthermic because of exercise, and the body temperature increases rather rapidly. The fighter will most likely continue to actively sweat, or at least will be sweaty from previous activity. There have even been recorded deaths in which the patient was never seen to have an elevated body temperature!

The hallmark of severe heat injury is the change in mental status. If the patient is confused, unable to walk properly, or even just acting unusually silly, they should be treated as if they are suffering from heat stroke. You should be suspicious even if it is not hot weather – the death I mentioned above occurred when the temperature was only 55^{o}F! While this is not the normal situation, you need to keep a high index of suspicion.

Treatment is immediate cooling in any way possible: remove clothing, douse them with mass quantities of cold water, ice on the groin and neck, and fans to rapidly decrease the body temperature. The victim should be transported *by ambulance* to the nearest emergency department as effects of heat stroke can occur many hours after the body temperature returns to normal. Long term effects can include brain edema (swelling), ataxia (unsteady walking), heart failure, DIC (disseminated intravascular coagulation), hemolysis (breakdown of red blood cells), myocardial infarction (heart attack), rhabdomyolysis (breakdown of muscle tissue that can lead to kidney damage), renal (kidney) failure, and liver failure.

Prevention is to recognize the early signs, ensure proper physical conditioning and heat acclimatization, adjusting activity to suit environmental conditions, and adequate hydration and diet.

Weak Link Theory

It bears repeating that if one person is presenting with a heat-related problem there are probably more to follow. Consider the first case you see as a warning that there are probably many more at the event who are close to becoming a casualty. Start pushing more fluids. Discuss the situation with the Marshals. Have the Heralds announce that people should be pushing fluids. A rapid response to the early warning signs can help prevent others from becoming victims. That includes the Chirurgeonate and Waterbearers. You can't treat patients if you yourself are a casualty.

Exercise, Heat, & Hydration

Reaction to Exercise

Exercise generates heat. In fact, 75% of the energy consumed during exercise is converted to heat. The increased muscle activity requires an increased supply of oxygen and glucose, which is provided by increasing the blood flow to the muscles. Heart rate and respiration increase to meet these additional demands.

Reaction to Heat

When the body starts to heat up, it dilates the blood vessels in the skin. Sweat can be produced at rates up to 3 liters per hour. The sweat is hypotonic, i.e., it has a lower concentration of salts (electrolytes) than the blood. Therefore, the body loses more water than salt, so the concentration of electrolytes in the blood can in theory actually *increase*. In actuality, the change in serum electrolytes is minimal.

Exercise in Heat

Exercising in a hot environment combines the above two reactions, which can cause a conflict over who gets the blood: the muscles are demanding an increased flow to support the increased workload, and the cutaneous (skin) vessels are trying to dilate to get rid of the excess heat. If the person is already slightly dehydrated, the body can't meet both demands. Therefore, heat loss is impaired, and athletic performance decreases. Also, if the environment is hot and humid, then the body's ability to lose heat is further impaired. Proper conditioning can help the body respond to the heat, and, if you haven't guessed already, so can proper hydration and diet.

Rehydration

To keep adequately hydrated, you must be able to keep up with the amount of fluids lost by sweating. The maximum amount of fluids the gut will absorb is about 1.5 liters per hour. Rather than guzzling large quantities once an hour, it is better to drink small amounts more frequently, for example 8 ounces every 15 minutes (one quart per hour).

But what about the participants who say "I don't need to drink, I'm not thirsty!" ? Thirst is a very poor indicator of hydration status. If you rely on thirst, then you are already about 1.5 liters low on fluid. A great indicator of hydration status is urine production. If the urine is clear or no darker than weak lemonade, then you are getting adequate fluids.

Don't Sweat It!

If it's been more than a couple of hours since the last trip to the privy, fluid intake is inadequate.

The subject of what to drink is quite debatable. Since sweat is less concentrated than blood, and heavy sweating tends to increase the electrolyte concentration in blood, it would make sense to replace losses with water. As long as diet is adequate (meaning you get enough salts over the next day or so to replace losses, and most American diets have *more* than adequate salt content), then water is a good choice. The only time problems have been seen with too much water is in ultra-marathon runners that push large quantities of water over many hours of exertion. Most athletes will do fine with just water. However, with the multi-billion dollar business in the sport-drink industry, there is certainly a push for electrolyte and carbohydrate drinks. These drinks are fine and some studies have shown them to help improve performance in exercise lasting greater than one hour. However, they should be diluted 50% with water to help absorption from the stomach and should not be the exclusive source of fluids and carbohydrates. These drinks can also help to increase fluid intake simply because they taste better than plain water. I like to take water and add lemons and orange slices. It adds enough flavor to keep them coming back for more. If the person is showing signs of heat exhaustion, they should be offered water first (it gets into the system faster), then replace the salts. If they are vomiting, then they need intravenous fluids.

There are many natural diuretics (substances that promote urine production) that are common at SCA events, primarily caffeine and alcohol. It doesn't make sense to be pumping in something that actually makes the body pee out more! Save these drinks for the evening revel after rehydrating with water. A word of warning to heavy caffeine drinkers: don't completely stop caffeine suddenly. Caffeine-withdrawal headaches are not pleasant, and can be confused with dehydration headaches. A sensible alternative is to decrease the caffeine intake and increase other fluids to make up for the caffeine-induced losses (remember the urine color rule of thumb!)

So, what is the best way to maintain fluid status during exercise? The American College of Sports Medicine has published a set of recommendations:

1. Eat a nutritionally balanced diet and drink adequate fluids in the 24 hours before an event.
2. Drink about 500 ml (17 oz) of fluid about 2 hours before exercise.
3. During exercise, drink early and often, enough to offset sweating loss.
4. Fluids should be between 59 and 72^{o} and flavored to enhance palatability.
5. Carbohydrates and electrolytes should be added if exercise is greater than 1 hour.

Another rule of thumb is "replace water hour by hour, and salt day by day. "

Practice Planning

Another way to help prevent problems it to limit activities during extreme heat. One way of doing this is to have alternative activities for practices when the heat index is adequate to fry eggs on helms. The heat index is similar to the wind chill: it combines heat and humidity to give you an estimate of what the temperature 'feels' like. The heat index is carried on local weather forecasts and the Weather Channel. It can be calculated from temperature and humidity on the World Wide Web at http://nwselp.epcc.edu/elp/heatindex.html, or if you are a true nerd, you can find the complete formula at http://usatoday.com/weather/whumcalc.htm.

Practice Recommendations

Heat Index 90 - 105^{o}	-	Reduce duration and intensity of practice.
Heat Index 105 - 130^{o}	-	Modify practice - no armor, shaded area, low intensity.
Heat Index above 130^{o}	-	Bag it! Grab a cool drink, sit inside in the air conditioning, and discuss war tactics.

Prevention

So, have I said it enough? I'd much rather prevent problems than treat them. So encourage adequate physical conditioning, heat acclimation, HYDRATION, and practice planning. Work with the marshals, educate the fighters, and keep an eye on the bystanders. Hopefully we can help keep our events safe from the scourge of heat injuries.