

What is thermoregulation ?

Maintenance of the human body requires numerous chemical reactions that operate best at a particular body core temperature.

We are described as homoeothermic or warm blooded and need to maintain a relatively constant core temperature for these chemical reactions, called metabolism, to occur optimally to produce efficient mechanical movement.

When engaged in exercise the body temperature is elevated as the metabolic rate increases to meet the energy demands of the work. From an efficiency view approximately 30% of metabolism is converted to mechanical work while the remaining **70% is expressed as heat**. Further heat, may be gained from exposure to the sun in the form of radiant heat or convection currents.

In order to preserve health and function optimally the body must find ways of dissipating this heat. Normally resting core temperature is about 98.6°F (-/+ 1°F) and may reach 102°F and higher in some individuals during exercise with or without adverse effects. There are various homeostatic mechanisms employed by the body in an attempt to maintain the core temperature within narrow limits. During, exercise there is increase blood flow to the skin—vasodilatation—to maximize heat loss. At the same time blood is diverted to the working muscles.

There is therefore an inherent competition between mechanisms that maintain a large blood flow to exercising muscles and those that provide adequate thermoregulation. Body heat is lost by radiation, conduction, convection and evaporation:

Radiation:

Heat transfer via electromagnetic heat waves through the air.

Conduction:

Transfer of heat by direct air molecules around body warmed by body heat.

Convection:

Heat loss via air currents moving warm air away from body.

Evaporation:

Evaporation of sweat from the skin surface is the most effective way to remove heat from the body.

When the sweat reaches the skin it evaporates and cools the surface causing a heat transfer from the blood. The cooled blood returns to the internal body environment where it absorbs heat from the tissues and the process is repeated.

Sweat:

Sweat is described as a hypotonic saline solution meaning that in comparison to body fluids it is a less concentrated salt electrolyte solution.

It contains over 99% water and only 0.2 to 0.4% sodium chloride—mainly sodium. When the body sweats the relative concentration of salt left in the body fluids is therefore increased. Only during exercise under extreme adverse conditions over prolonged periods are significant amounts of electrolytes lost. Normally after exercise sufficient electrolytes replenished at meal times.

The fluid in sweat comes from the extra cellular fluid of the blood plasma and that bathing the cells. Sweating therefore places demands on the body's fluid reserves and creates a relative state of dehydration.

NB: Sweat does not cool the skin.

Why is Thermoregulation important ?

The primary focus of thermoregulation is of course the continued health of the individual. However, failure to control body heat will also work to the detriment of performance.

If fluid loss exceeds replacement, dehydration can occur. This may result in decreased blood pressure, increased heart rate, decreased blood to working muscles and the skin, and subsequent decrement in exercise performance.

The individual may also be at risk of developing heat illnesses, such as heat cramps, heat exhaustion and heat stroke.

Dehydration

Dehydration during exercise in the heat occurs primarily from sweating which causes a decrease in circulating blood volume. An associated decrease in blood pressure places stress on the cardiovascular system trying to distribute adequate blood to the working muscles and at the same time diverting blood to the skin for heat exchange.

This decrease in blood volume causes the heart rate to increase in an attempt to provide blood flow needed to meet the energy demands of the exercise. As dehydration continues exercise performance and the sweat mechanism is compromised and the body temperature increases accordingly.

This juggling of circulatory adjustments in an attempt to cool the body also causes early accumulation of lactic acid with subsequent premature use of glycogen stores and early fatigue. Decreased blood flow to working muscles reduces the body's capacity to buffer and oxidize lactic acid. In an attempt to maintain blood to these muscles, hepatic (liver) blood flow is lactate uptake and oxidation by the liver.

Both factors are interrelated and contribute to early fatigue during even moderate exercise in the heat.

NB: Thirst and dehydration are not synonymous and thirst is a poor indicator of dehydration.

At commencement of thirst a person may already be dehydrated 2 to 3%. A decrease in performance will occur at all levels of dehydration. As the level of dehydration increases, performance levels will continue to drop.

Fluid loss equal to 3% of body weight can cause a significant reduction in aerobic work capacity ranging from 6% to 15%. Further fluid losses of 4% or 5% can cause declines in performance by 20% to 30% (Wilmore JH et al, 1994; Nadel et al, 1987, cited in Meir et al., 1995; Murray R, 1996). Note that these decrements in performance may be heightened depending upon the fitness of the individual and relative conditions on the day.

Fluid losses from the body can be expressed in terms of weight lost. That is for every one kilogram of weight lost during exercise one litre of fluid has been lost—adjusted for any intake of fluid or urine voided.

1 kg weight lost — 1 litre body fluid lost.

Example:

80kg player x 2.4% weight loss = 1.92 litres, i.e. approximately 2 litres of fluid lost.

Heat Illness:

The most important issues of thermoregulation concern the health of the individual in avoidance of hyperthermia and associated heat illness. The major forms of heat illness in order of severity are heat cramps, heat exhaustion and heat stroke.

"There is often no clear-cut demarcation between overlap. When heat illness does occur however, immediate action must be taken to reduce the heat stress and rehydrate the person until medical help is available "(McArdle W. et al, 1996).

Heat Cramps or involuntary muscle spasms usually occur in the specific muscles exercised after prolonged intense work. Body temperature may or may not be elevated. They are thought to occur as a result of water loss rather than salt depletion, causing an imbalance in the body's electrolyte concentrations.

Heat exhaustion can develop in unacclimatised individuals early in the season during hot humid weather. Exercise-induced heat exhaustion is believed to occur due to ineffective circulatory adjustments and depletion of extracellular fluid—particularly blood plasma volume—from excess sweating.

Blood tends to pool in the periphery due to the dilated blood vessels markedly reducing central blood volume and cardiac output (McArdle et al, 1996).

Therefore the cardiovascular system struggles to adequately meet the body's needs. Signs and symptoms include extreme fatigue, weak, rapid pulse, low blood pressure in an upright position, headache, and dizziness, Sweating may be reduced and body temperature elevated to 39°C but not above dangerous levels around 40°C.

A person suffering these symptoms should cease exercise and rest in a cool environment. Heat exhaustion can deteriorate into heat stroke if allowed to progress (Wilmoye JH et al, 1994), Summon medical assistance. If conscious, fluids should be administered orally but if unconscious an intravenous feed of saline is recommended.

Heat Stroke is the most serious and complex heat stress malady and requires immediate medical attention. Heat stroke is caused by failure of the in excessively high body temperature which is life threatening.

The sweating response normally shuts down and the skin is dry and hot, body temperature rises to 41.5°C or higher and severe strain is placed on the circulatory system. However there have been instances reported where some individuals body temperature has only reached 39°C during heat stroke and in others where sweating has continued to occur so the skin presents as wet and not dry. This may occur particularly when the relative humidity is high which prevents the evaporation of sweat from the skin.

This highlights the importance of recognizing the peculiarities amongst individuals and not fall prey to recipe diagnosis and treatment.

Because heat stroke is a medical emergency aggressive steps need to be taken whilst awaiting medical treatment.

The elevated core temperature needs to be rapidly reduced as mortality is related to both the magnitude and duration of hyperthermia. Immediate treatment may include alcohol rubs, fans, cool baths and ice packs but do not promote shivering—shivering promotes an unwanted increase in body heat.

Oral temperature is often highly inaccurate due to the heightened pulmonary ventilation—increased breathing—during and immediately post exercise. The oral temperature is therefore influenced by the evaporative cooling effect in the mouth from passing air currents. Rectal temperature is far more accurate.

When exercising in the heat, if you suddenly feel chilled and goose bumps form on your skin, stop exercising, get into a cool environment and drink plenty of cool fluids. The body's thermoregulation system has become confused and thinks that the body temperature needs to increase even more! Left untreated this condition can lead to heat stroke and death. (Wilmoye JH et al, 1994)

What are the risk factors?

Relative Humidity and Heat:

The amount of relative humidity and heat on the day are extremely important. The humidity is the amount of water vapour carried in the air relative to its carrying capacity at a given temperature.

This bulb temperature and is most significant with regard to thermoregulation. Playing or training when the wet bulb temperature is high—hot humid conditions— reduces the temperature gradient between skin and air and the sweat tends to pool on the surface of the body.

Hence there is little chance for the sweat to evaporate and the body quickly overheats.

Type and Colour of Clothing:

Tight fitting clothing does not allow air flow to assist in evaporative or convective cooling. Similarly clothing that does not "breathe" for example, nylon and polyester, does not allow absorption and removal of sweat. Instead they promote a warm layer of fluid between the garment and body similar to the diving wetsuit.

Dark colours attract more heat especially black jerseys. Black reflects no colour and therefore absorbs all light and heats up significantly. On the other hand white reflects all the colours and is much cooler.

People Susceptible to Hyperthermia.

- Larger people as they have a decreased surface area to body volume ratio and thus a decreased heat transfer from the body.
- Obese people for the above reason and because fat is a good insulator, reducing heat loss.
- Unfit people as heat produced is dependent on the intensity of exercise, unfit individuals work harder at a higher relative intensity to keep up with fitter players.
- Ill people or those recently unwell who have had fever, diarrhea or vomiting, will commence playing in an already dehydrated state.
- People unacclimatised to heat will not sweat or supply blood to the skin as effectively. Therefore, ensure there has been adequate time for acclimatization to the effects of heat
- Avoid alcohol the night before and caffeine based beverages (cola drinks) to avoid their diuretic effects.
- Children have a reduced sweat mechanism, sweat less and sweat less precisely, and they have a higher core temperature during heat stress. They usually require longer to acclimatize to heat. Children also have a larger surface area to body volume ratios which can help heat loss but may also allow greater area for radiant heat gain.

Hydration

Hydration is the absorption of fluid into the body and water is the most popular medium. The aim is to replace the level of body fluids lost mainly through sweat although this is seldom possible during exercise in adverse conditions. It is important therefore that all attempts are made to replace as much fluid as possible.

In extreme heat, hydration should commence the night prior. On relatively cool or cold days hydration can be commenced 5-10 minutes prior to warm-up, provided the individual is hydrated—i.e. normally hydrated.

Clear urine is a broad indicator of an adequate level of hydration but fluid should be replaced after voiding.

The rate of gastric emptying from the stomach to the small intestine is important as very little water is absorbed via the stomach itself. The gastric emptying rate of plain water is about 1 litre per hour for adults at rest—i.e. 250ml/15 minutes— but can vary. Cool to cold fluids tend to empty more rapidly, may help reduce core temperature and are generally more palatable.

Individuals vary in their gastric emptying rates as well as their tolerance to gastric volumes during varying exercise intensities. Gastric upset can occur with high exercise intensities— above 70% to 80% VO max—but again this varies amongst individuals. It is unclear whether complaints of gastrointestinal symptoms by players are a function of an unfamiliarity of exercising with a full stomach or because of delays in gastric emptying. Care should also be taken not to overload and distend the stomach to uncomfortable lengths as this will hinder expansion of the diaphragm muscle during exercise

It is therefore recommended that / individuals learn their tolerance limits for maintaining high gastric fluid levels for various exercise intensities and duration whilst at training. Often gastric distress is more associated with dehydration or attempts at re-hydration from a dehydrated state.

In order to prevent dehydration and gastric distress a basic guideline, for adult players would be the consumption of 400 to 600 ml of fluid either immediately before or 10 to 15 minutes prior to play and then regular ingestion of 150 to 250 ml of fluid at 15 minute intervals during play may be required depending upon the conditions on the day.

Determining Sweat Rate:

Due to the dehydration/thirst anomaly a hydration plan should be adopted and calculated on individual sweat rates during a game and not on ad libitum fluid intake. Under different exercise conditions sweat rates can vary from 1 litre per hour to as much as 3 to 4 litres per hour under extreme conditions. The rates can also vary widely amongst individuals.

Thermoregulation on a hot day:

Rest in shade at half-time taking advantage of any air currents available for convective and evaporative cooling.

Remove jerseys and wet down body to maximize surface area for evaporative cooling or use wet towels to promote conductive cooling.

Do not promote shivering as this causes muscle contraction of hair follicles resulting in unwarranted generation of heat.

Remove head gear as nearly 30 to 40% of body heat can be lost through the highly vascularized head region even though it only represents about 8% of the body's total surface area (McArdle et al., 1996)

Wet down head with water.

In relatively low humid conditions do not replace wet jersey's with dry ones to take advantage of evaporative heat loss and the fact water conducts heat faster than air. However in high humid conditions consider a change of jersey— if practical—to promote heat loss. Because sweat stays on the skin in humid weather it forms a warm layer beneath the jersey. As there is little or no evaporation of sweat from the jersey itself transfer of heat through the wet jersey does not occur.

Water or sports drink?

Water is the universal medium and is usually hypotonic.

As mentioned earlier sweat is also hypotonic so that during exercise as dehydration progresses the concentration of electrolytes in the body fluids become progressively more concentrated.

NB: The need to replace body water is therefore greater than the need for electrolytes because, only by replacing water is the concentration of electrolytes returned to normal.

Given that ingested fluid in the gut is technically outside the body an isosmotic or hypotonic solution would be the favoured hydration medium.

Sports Drink:

Sports drinks offer dual advantages of hydration and carbohydrate feeding to delay fatigue. Past scientific findings did not support exogenous carbohydrate feedings to sustain mixed anaerobic and aerobic activities such as rugby league.

Recent studies however have supported delayed onset of fatigue with supplementation of such feeding's during exhaustive repetitive bouts of anaerobic activity. Enhanced performance has been linked to maintenance of blood glucose and sparing of liver glycogen levels, increased muscle glucose and possible increase in muscle glycogen levels.

Some research suggests that a sports drink with a low concentration of an electrolyte and carbohydrate solution has a low osmotic count and has advantages over plain water as a re-hydration medium.

Commercially prepared sports drinks containing 6% carbohydrate, preferably a glucose polymer, with 20mm of sodium per litre are typically described as isosmotic. These fluids are absorbed relatively quickly from the gut—assisted via active pump—and promote greater fluid retention post exercise through reduced urine production (Burke, L., 1996).

The current recommendation is to avoid solutions of carbohydrate greater than 8% concentration with high osmolarity to reduce the temporary shift of fluid into the gut and decreased rate of gastric emptying.

Similarly electrolyte concentration should be kept to a minimum to avoid further temporary dehydration due to the lower concentration of sweat relative to body fluids—0.5-0.7 grams per litre of water should be sufficient to enhance palatability and promote fluid retention (Murray, R., 1996).

The improved palatability of sports drinks tends to enhance voluntary drinking compared to water both during and post exercise and varies between individuals. When assessing palatability one should appreciate that perception of taste changes at rest compared to exercise.

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