# The Science of Cycling in the Summer Heat

Given the approaching summer cycling season, it is a particularly appropriate time to discuss the impact of heat stress on cycling performance and training. It is first necessary to understand the basics of human thermoregulation to prepare for a discussion around three strategies that can be used to help when training and racing in the heat: hydration, heat acclimation, and fitness.

Fundamentally, the body is in constant interaction with the ambient temperatures surrounding it, while trying to maintain a constant core body temperature. The major pathways of heat exchange are evaporation (sweating), convection (between the body and the air), conduction (direct contact between the body and another object), and radiation (between the body and infrared waves). While riding on hot summer days, the body gains heat through convection (high air temperature), conduction (hot pavement, handlebars, etc.), and radiation (hot sun) which makes it particularly hard to maintain the core body temperature. Likewise, the physical work from riding adds a significant heat load to the body. The body's main mechanism of heat loss is through sweating (evaporation) where hot blood from the core is shuttled to the skin and is cooled. This process, however, is demanding on the body's available fluid. Increased blood flow and a high sweat rate can result in dehydration and cardiovascular strain making training, racing, and even decision making quite difficult. Under these conditions, a rider may see higher heart rates, lower absolute power outputs, decreased maximal oxygen consumption ($VO_2$max), and slower reaction times while out on a ride.[1] Eventually when the cooling mechanisms in the body fail to keep up with the heat load, core body temperature will increase and may result in heat-related illnesses that range from heat cramps to a fatal condition of heat stroke.[2,3]

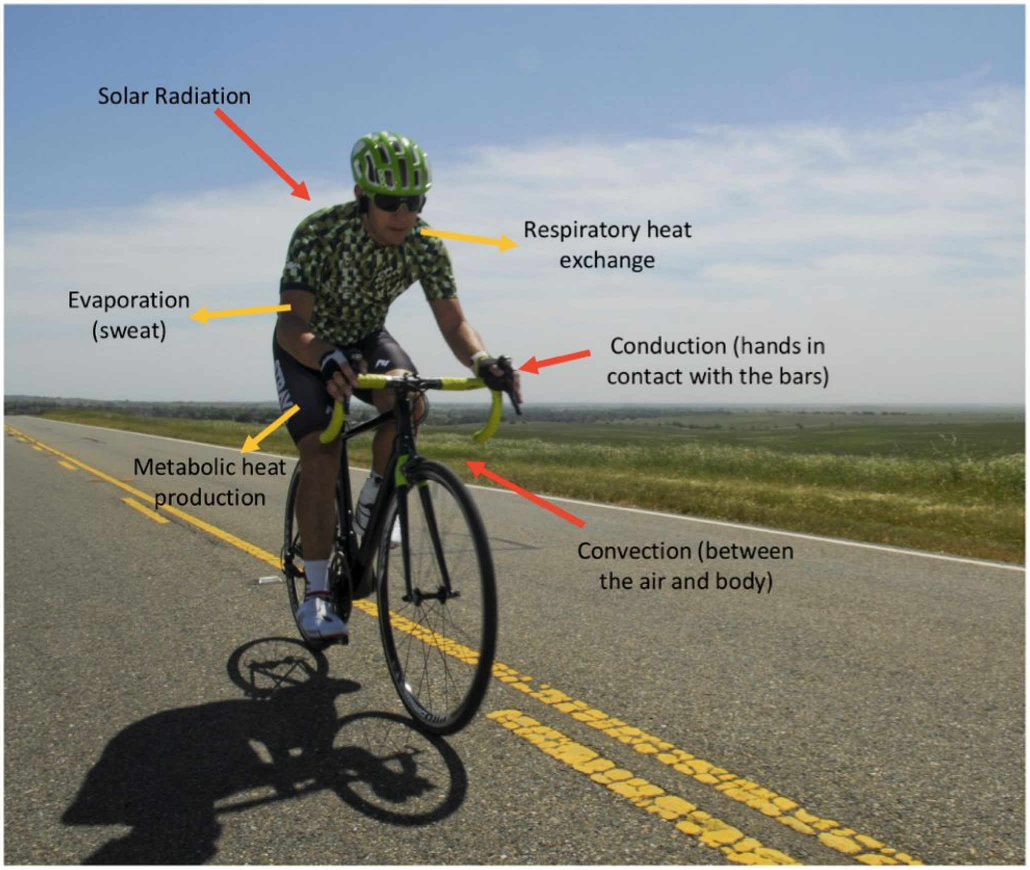


Figure 1 – Pathways of heat exchange

Hydration

The first and most intuitive strategy for combating heat stress is hydration. In the heat, we sweat more so we need to drink more to replace the loss, simple enough. In addition to water, the body is losing electrolytes through sweat, making electrolyte replacement important as well. The American College of Sports Medicine published a position stand on exercise fluid replacement in 2007 and is the standard for recommendations on the topic.[2] While the position stand gives general recommendations, it is important to keep in mind that every individual is different in how much they sweat and how much fluid replacement is needed. Before competition, pre-hydration should be done at least several hours before the event with the goal of normalized urine output and light-colored urine. Current recommendations suggest slowly intaking

~5-7mL/kg body weight 4 hours prior to competition.[2] If urine is still not produced or of dark color, slowly consume another ~3-5 mL/kg body weight.[2] Additionally, consumption of sodium rich drinks and snacks can help the body retain fluids ingested and maintain thirst.

The optimal hydration strategy during competition or exercise is very person and condition dependent, however in general, your hydration strategy should aim to avoid a loss greater than 2% of body weight. Testing is required to determine the optimal hydration strategy during competition because every individual is so different. While there are laboratory grade tests for this, the simplest way to test exercising sweat rate is to calculate the change in body weight before and after a workout in a specific environment mimicking that of the environment of interest (i.e. test on a hot day if you're going to use the data for a mid-summer race plan). First, measure your nude body weight after voiding your bladder first thing in the morning. Do this on 3 separate days (a couple more for women) and take the average to provide a baseline euhydrated body weight. Morning body weight is the most stable (within ~1%) and most likely to represent a euhydrated body.[4] This average weight can be used to develop a hydration program and to monitor acute hydration status day-to-day.

On the day of testing, weigh yourself in the morning using previously described methods and make sure your body weight is within ~2% of your previous average. Exercise for 1-hour at the expected competition intensity and environmental conditions. Ideally, this is done on flat or rolling terrain to control intensity. Take a post-exercise nude body weight after drying off excess sweat from the body.[5] The total weight change after correcting for urine loss and fluid intake can be used to calculate sweat rate per hour. Every 1-gram body weight lost is equal to 1 mL of sweat loss (specific gravity of sweat is 1.0 g/mL). Other forms of water loss such as respiratory water loss cannot be measured using this method so estimates of sweat rate will be slightly overestimated (~5-15%). However, in durations of exercise less than 3 hours, generally this is ignored. Individualized hydration plans for exercise in the heat can be developed from this sweat rate with the goal of replacing all fluids lost to sweat per hour.[2]

Post-exercise hydration strategies have the main goal of returning the body to a euhydrated status. Therefore, the previously calculated baseline should be used as a goal to meet when rehydrating post-exercise. protocol.

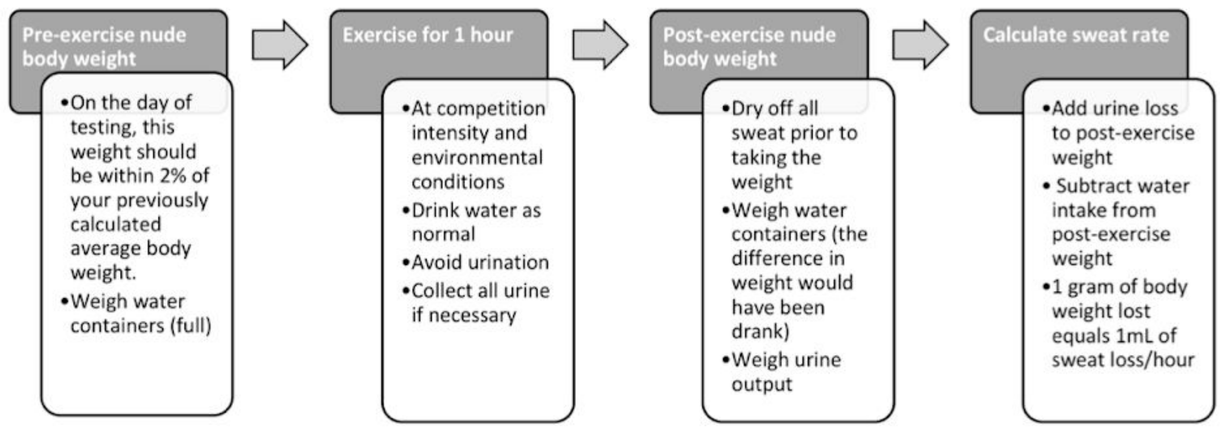


Figure 2 - Hydration testing protocol

## Heat Acclimation

Heat acclimation is one strategy that can be used to decrease the performance deficits elicited by cycling in high heat environments. Heat acclimation anywhere from 4-14 days has been shown extensively to provide beneficial thermoregulatory and cardiovascular adaptations such as lower core body temperature and metabolic rate as well as increased sweat production, skin blood flow, exercise performance, thermal comfort, and fluid balance.[6 7 8] Mainly, heat acclimation improves thermoregulation through increased sweat rates, thus improving heat dissipation. This then decreases cardiovascular strain, allowing for higher staining workloads compared to before acclimation.[7] One study reported a 5% increase in power output at lactate threshold and 8% increase in $VO_2$max in a hot environment (38°C and 30% relative humidity) following 10 days of heat acclimation compared to before heat acclimation.[9] The most effective heat acclimation protocols typically involve completing moderate to vigorous intensity exercise (at least 50% $VO_2$max) on at least 5 consecutive days in high heat environments (>35°C and moderate to high humidity). If there aren't 5 consecutive high heat days, additional acclimation days are required. Significantly increased sweat rate is typically thought of as the final sign of being appropriately acclimated.[10] Therefore, previously described methods of sweat rate calculations can be completed before and after acclimation as a rudimentary marker of sweat rate changes and heat acclimation status. However, given the significant effect of heat acclimation for sweat rates, hydration protocols should be adjusted based on acclimation status as necessary throughout the summer season.[2]

Fitness

The final strategy in combating known decrements in cycling performance related to heat is through fitness. It is well established that heat exposure decreases $VO_2$max. [11-13] Decrements in aerobic performance have been shown to be independently and concurrently related to increased skin temperature and core temperature, with the suggestion that the decreased performance was due mainly to cardiovascular strain rather than central nervous system strain [13]. This provides good news because cyclists can train the cardiovascular system to adapt over time to these stresses. A more fit individual will be able to work at the same absolute power output at a lower relative intensity, requiring less cardiovascular strain, and therefore be more fatigue resistant in the heat. Furthermore, it has been reported that those with high fitness levels can acquire greater tolerance to higher core body temperatures than those who are less fit.[14]

However, as previously discussed, dehydration plays a significant role in cardiovascular strain seen in hyperthermia and the resulting decrement in aerobic performance [13 15 16]. Therefore, increased sweat rate in hot and humid environments, while acting to support thermoregulation, can negatively affect performance when resulting in marked dehydration [15 17-19]. Furthermore, evidence has suggested that aerobic training promotes an increased sweat rate for a given core temperature [20-24] that, in conjunction with increased skin blood flow, provides improved heat dissipation in trained individuals as compared to the untrained [20 22]. However, in high heat stress environments, it has been proposed that this increased sweat rate may lead to decrements in performance due to dehydration and a resulting decrease in cardiac output [16]. Increased sweat rate has also been shown to be exaggerated at higher intensity exercise [21]. It has also been shown that heat stress may reduce VO2max in trained individuals as a result of diminished cardiac output, exercising muscle blood flow, and O2 delivery [26]. These effects are hypothesized to be induced by increased dehydration from high sweat rate in trained individuals [26]. In other words, those who are trained may see greater thermoregulatory adaptations than those who are less trained. However, the greater sweat rates seen in more trained individuals can potentially serve to decrease performance over time if proper hydration is not maintained.

In conclusion, high heat and humidity provides a particularly challenging environment to ride compete in at a high level. Decrements in performance are seen through cardiovascular re-prioritization to the thermoregulatory processes and away from exercising muscle. These decrements in performance can be mitigated through proper hydration, heat acclimation, and improved fitness. Additionally, there are interactions between these three strategies that must be considered. Frequent testing and concurrently redefining hydration protocols based on current fitness level, environmental conditions, and acclimation status is recommended.

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