Beat the heat

World Triathlon

Be your extraordinary

Contents

Triathlon is an Olympic and Paralympic multisport event comprised of swim, cycle and run disciplines performed consecutively and completed over a variety of distances.

Typically, triathlon events are held in the summer where athletes can be exposed to particularly hot and humid environmental conditions. Under overly oppressive conditions, both the capacity to perform and the health of athletes can be negatively impacted.

This document addresses Frequently Asked Questions regarding how to approach triathlon events held in very hot and humid conditions, particularly in the preparation for Tokyo 2020, and provides recommendations to optimise performance and minimise the occurrence of heat illness.

How is core temperature regulated?

Core body temperature at rest is maintained at around 37°C. During exercise, core temperature increases in response to a combination of metabolic heat production, which is directly aligned to the intensity of exercise, and the prevailing ambient conditions, which influence heat exchange with the environment.

A plateau in core temperature may occur anywhere around 38.5-39.5°C when exercising in cool environments. However, some athletes may reach a core body temperature in excess of 41°C when competing in hot ambient conditions [1]. The environmental factors that influence heat exchange (heat gain or loss) during exercise include ambient temperature, humidity, solar radiation, and wind speed. These factors affect the pathways of heat exchange: conduction, convection, radiation, and evaporation [2].

For paratriathletes, the impairment of the athlete can influence their capacity for heat loss. Athletes with a spinal cord injury may display a significant impairment in thermoregulation, characterised by an inability to sweat below their lesion [3]. Limb-deficient athletes have a lower body surface area and therefore a reduced ability for heat loss to the environment [4]. Athletes with gait asymmetries can demonstrate higher metabolic heat production for a given work rate due to their movement inefficiencies [5].

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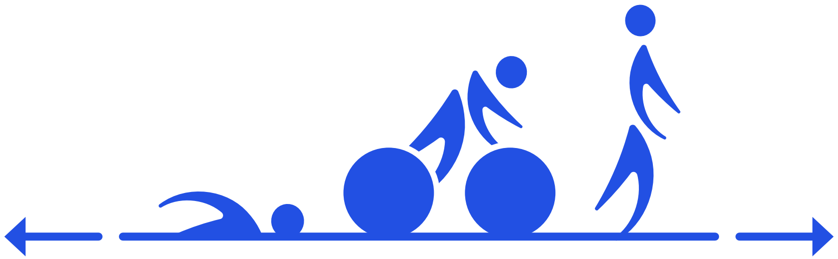
Figure 1:
Heat exchange pathways during exercise in the heat

Radiation

Heat transfer via electromagnetic waves from the sun. Waves can be direct, diffused through clouds, or reflected off the ground or other surfaces.

Evaporation

Heat loss via the vaporisation of sweat from the skin. Evaporation is the main avenue of heat loss during exercise in the heat. Sweating efficiency is reduced in humid environments.



Convection

Heat transfer via the movement of fluids like water and air. Heat is lost when air/water temperature is lower than the skin. Heat is gained when air/water temperature is higher than the skin.

Conduction

Heat transfer via direct contact of different surfaces. Conductive heat exchange is negligible during exercise.

How does environmental heat stress affect triathlon performance?

Swim

The swim leg of the triathlon ranges from 375m to 4,000m depending on the event. Given that swimming is the first discipline of a triathlon, the rate of rise in core body temperature is greatest during that part of the event.

The increase in core temperature occurs in response to the rise and maintenance of a high level of metabolic heat production, which can increase core temperature above 39°C [6]. The rate at which core temperature increases depends on the intensity at which the athlete is swimming, as well as the water temperature. When swimming is undertaken in 32°C water compared with 27°C for example, performance across 20 to 120 min events decreases by 4-7% [6].

Bike

The impact of hot environmental conditions on endurance cycling performance (20 km and above) is well documented, with average power output decreasing by about 15% in hot (30°C) compared with cool (20°C) conditions [7]. The impairment in performance occurs in conjunction with the increase in whole-body temperature

[8, 9], which leads to an increase in the cardiovascular response and in turn a progressive decrease in maximal aerobic capacity (VO2max) [10, 11]. As a result, athletes decrease their absolute work rate (power output) in the heat to maintain a relative exercise intensity and effort similar to that of cooler conditions [12].

During a triathlon race, whole-body temperature is already elevated at the start of the cycling leg since the athletes have just completed the swim leg. The reduction in cycling performance can therefore be expected to occur earlier than when conducting a standalone cycling race, depending on the dynamics, tactics, and geography of the course.

Compared to ambulant paratriathletes, PTWC paratriathletes (wheelchair users) may be at particular risk for thermoregulatory strain during the handcycling leg of the race. Due to the low surface area for convective heat loss, closer proximity to the road and potential radiative heat gain, and the nature of athletes' impairments, greater core temperatures have been shown in this population group [13].

Run

Running in hot conditions is affected in a similar way to cycling, with longer events incurring a greater reduction in performance under hot environmental conditions

[15, 16]. Similar to the cycling leg, whole-body temperature at the start of the run will be elevated. Given that running occurs at a slower speed than cycling, the potential for heat loss via convection and sweat evaporation is reduced. The running leg is therefore the section of the race where athletes may be most at risk of experiencing exertional heat illness.

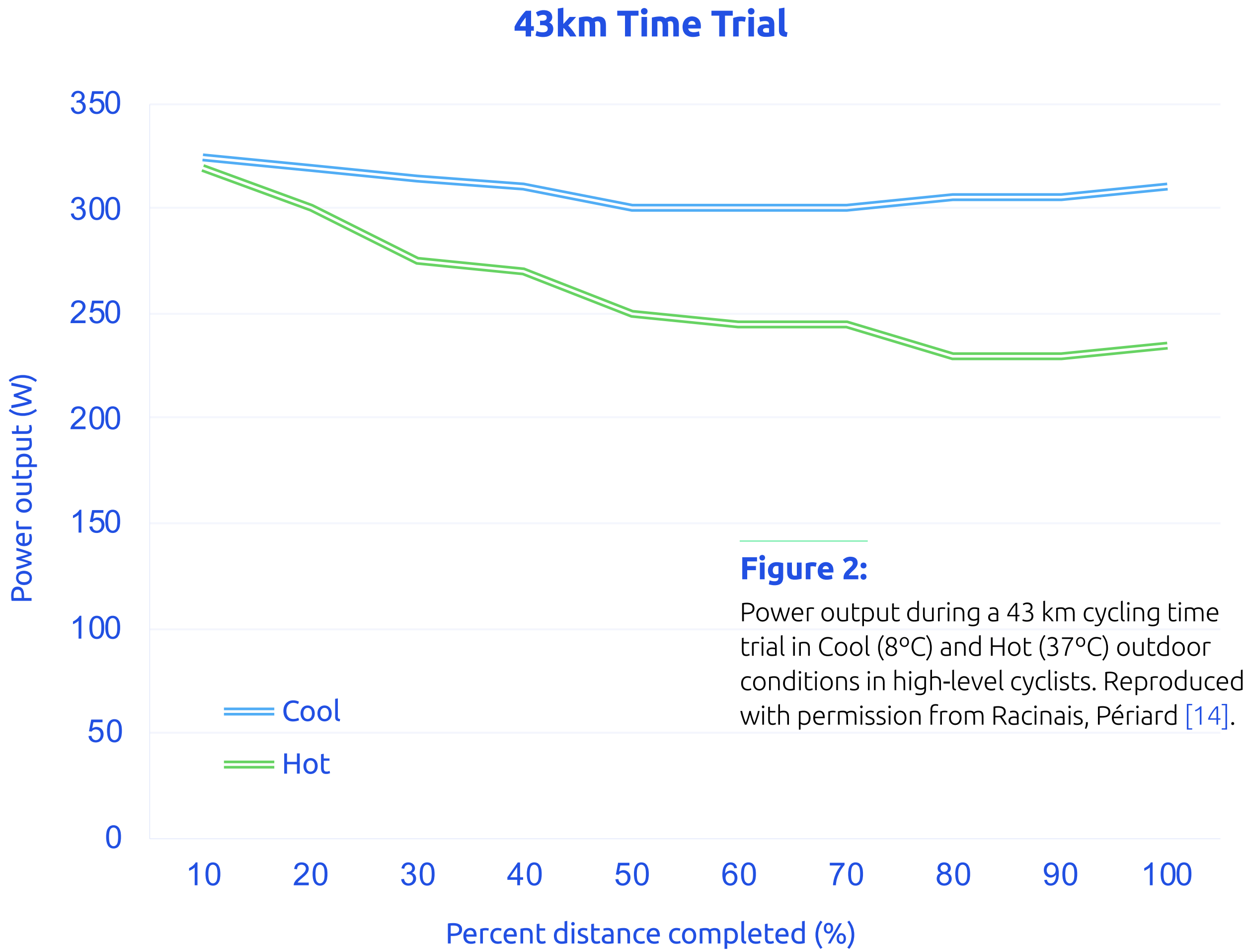


Figure 2:
Power output during a 43 km cycling time trial in Cool (8°C) and Hot (37°C) outdoor conditions in high-level cyclists. Reproduced with permission from Racinais, Périard [14].

How does environmental heat stress affect athlete health?

Exertional heat illnesses represent a continuum of medical conditions with potentially deadly consequences that can affect physically active individuals in hot and cool environments.

The severity of exertional heat illness can range from heat exhaustion, to heat injury, and on to exertional heat stroke [17]. Unlike classic heat stroke, which is primarily observed in very young and elderly populations during seasonal heat waves, exertional heat stroke often occurs in young healthy individuals considered low risk and performing routine physical activities, such as exercise in cool or hot environmental conditions.

Exertional heat illness susceptibility is multifactorial, with the greatest risk shown during midday activity, early-season heat waves, and when traveling to unaccustomed oppressive climates [18]. Having recently experienced an illness and/or being in an immunocompromised state also increase heat illness susceptibility [17].

Figure 3:
Heat illness continuum. Increasing levels of heat strain may lead to heat exhaustion, heat injury and heat stroke

Heat exhaustion

- Minor central nervous system dysfunction: headache, faintness
- Possible dehydration
- Increased skin blood flow
- Decreased cardiac output
- Decreased blood pressure

Heat strain level

Heat injury

- Minor central nervous system dysfunction: headache, faintness
- Tissue and organ dysfunction: skeleta muscle, liver, kidneys
- Tissue and organ injury
- Increased circulation of injury biomarkers

Heat strain level

Exertional heat stroke

- Profound central nervous system dysfunction: seizure, combativeness, loss of consciousness
- Rhabdomyolysis and endotoxemia
- Systemic inflammatory response
- Multi-organ failure and death

Heat strain level

How to best prepare for competing in the heat?

The most important intervention one can adopt to reduce physiological strain and optimise performance is to heat acclimate.

Heat acclimation improves temperature regulation and enhances endurance exercise performance in warm and hot environmental conditions. The benefits of heat acclimation are achieved through an expansion of plasma volume, enhanced cardiovascular stability, improved sweating and skin blood flow responses, better fluid balance (hydration status), and acquired thermal tolerance [19, 20]. The process of adaptation occurs over 7 to 14 days and can take place in laboratory/indoor settings (heat acclimation), or following exposure to natural outdoor environments (heat acclimatisation). The adaptive process is achieved via repeated exercise-heat exposures of 60 to 90 min that increase body core and skin temperature, as well as induce profuse sweating.

Research has shown that Paralympic athletes are also capable of heat acclimating [21, 22]. However, the extent of adaptations may be dependent on the athletes' impairment. For example, athletes with a complete spinal cord injury will not show improved sweating due to their impairment.

Figure 4:

Power output during a 43 km cycling time trial in Cool conditions (8°C) and after 2 days (Hot 1), 1 week (Hot 2) and 2 weeks (Hot 3) of training in 37°C outdoor conditions in high-level cyclists.

Reproduced with permission from Racinais, Périard [14]

World Triathlon

What sort of performance benefit can I expect from heat acclimation?

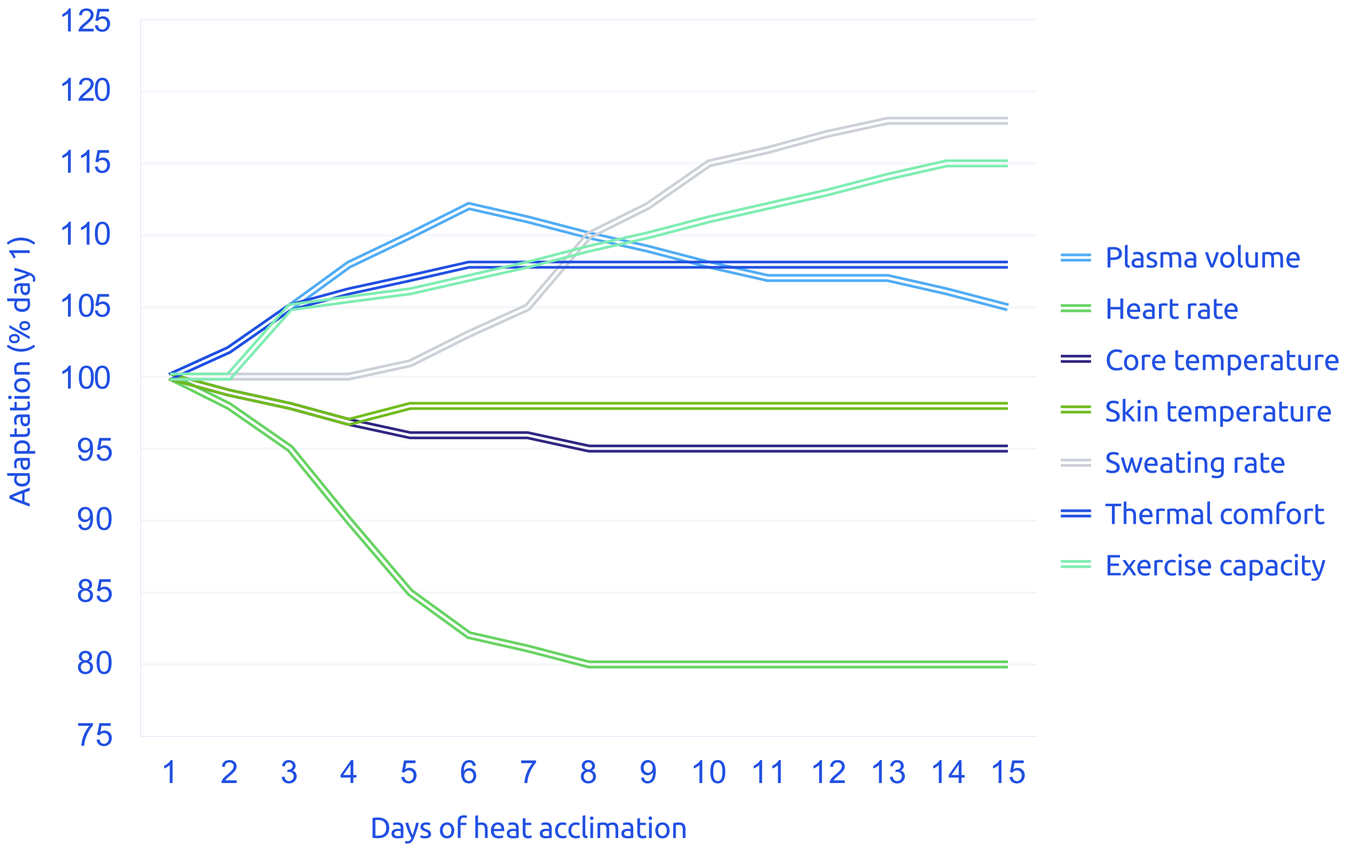
Environmental heat stress can significantly impair endurance performance. However, heat acclimation allows restoration of much of this impairment in performance and reduces the risk of heat illness [14].

Heat acclimation should be prioritised prior to any event where the environmental conditions are forecasted to be hot and/or humid, even if the level of heat stress is uncertain. It is important to note that heat acclimation does not impair performance in cool environments and may even increase it under some circumstances **[23]**.

Figure 5:

The time course of adaptations to exercise-heat acclimation.

Within a week of acclimation, plasma volume expansion occurs and heart rate is reduced during exercise at a given work rate. Core and skin temperatures are also reduced when exercising at a given work rate, whereas sweat rate increases. Perceptually, the rating of thermal comfort is improved. As a result, aerobic exercise capacity is increased. Of note, the magnitude of these adaptations is dependent on the initial state of acclimation and the acclimation protocol (e.g. environmental conditions and exercise intensity). Reproduced with permission from Périard, Racinais [19].



What type of approach should I use in order to heat acclimate?

Several approaches can be used to induce heat acclimation. The key is to increase whole-body (core, skin and muscle) temperature and stimulate sweating.

The ideal scenario would be to heat acclimate in the same environment as the upcoming competition. However, if this is not possible, heat adaptations can be acquired by simulating hot conditions in an indoor setting such as an environmental chamber, or even in a room with portable heaters. It is also possible to use passive heat acclimation techniques such as hot water immersion or sauna bathing following a training session. This approach takes advantage of whole-body temperature being elevated from training and allowing it to be maintained or increased passively to provide an additional stimulus for adaptation.

Exercise and passive heat acclimation protocols have been shown to be effective for Paralympic athletes. When selecting an acclimation protocol, however, athletes and coaches should consider the athlete's impairment. Firstly, due to a reduced ability to sense heat through the skin, athletes with a spinal cord injury may be unaware of the level of heat stress imposed by the environment and thus should be closely monitored during heat acclimation.

Athletes with a high lesion level will display a blunted heart rate response to exercise that may make a controlled heart rate protocol ineffective. Additionally, if using controlled hyperthermia, rectal temperature is not advisable for athletes with a spinal cord injury due to the risk of autonomic dysreflexia (a potentially life-threatening bout of extreme, uncontrolled high blood pressure resulting from severe blood vessel narrowing and cardiac stimulation; [24]). In athletes with cerebral palsy, self-paced exercise may not be appropriate as research has shown perception of effort and pacing may be impaired in this cohort [25]. Whilst visually impaired athletes display no obvious impairment to thermoregulatory function, those with the lowest visual acuity (e.g. PTVI B1; most visually impaired paratriathletes) may lack the ability to see their internal or external workload for intensity regulation. Finally, from a practical perspective, if passive heating is used, accessible facilities should be sourced for athletes with significant impairments to mobility.

Figure 6:
Overview of heat acclimation and heat acclimatisation methods with activity examples. Various combinations of temperature and humidity are possible. RH: relative humidity. Reproduced with permission from Daanen, Racinais **[26]**

How and when do I implement heat acclimation in my regimented training program?

A key question for elite athletes regarding the implementation of heat training is when to schedule it in the overall training program, and in particular ahead of competing in the heat so as not to interfere with the taper period.

A 1-2 week heat acclimation regimen implemented 4-6 weeks prior to competition could be integrated into the training program. This approach could then be supplemented with regular passive heat exposures during the weeks prior to competition, or a short (2-4 day) re-acclimation period the week before competition. This approach would provide a constant stimulus for maintaining adaptation and minimally affecting regular training in the lead up to a race. It is also suggested because re-acclimation, when undertaken within a month of the original acclimation period, leads to a faster (re)induction of adaptations [26]. Although exercise-heat exposure during the taper may help maintain the benefits of heat acclimation, it may also interfere with the goal to reduce overall training load. As such, passive heat exposure (sauna or hot bath) following training sessions in a cool climate may be utilised during the taper period [27, 28].

The following figure summarizes some of the different approaches that can be adopted in preparing for competition in the heat, based on available time, resources, and arrival to the competition venue. Athletes arriving early (1-2 weeks) can (A) initiate the adaptation process by conducting 1-2 heat exposure sessions per week for 4-8 weeks prior to traveling and then training outdoors in the heat once on site, or (B) undertake 7-14 days of heat acclimation 4-6 weeks before departure followed by one heat-exposure maintenance session(s) per week prior to traveling and then training outdoors in the heat once on site. Athletes arriving late (1-3 days) can (C) heat acclimate for 7-14 days 2-3 weeks before traveling and conduct a heat exposure maintenance session(s) in taper week prior to traveling, or (D) extend this approach by heat acclimating 4-6 weeks before departure and performing a short (3-4 days) re-acclimation protocol the week prior to traveling. The heat acclimation maintenance sessions in strategy B (weeks 3, 2 and 1), C (taper week) and D (weeks 3, 2 and 1) are not required but will help maintain adaptations. Based on individual circumstances (e.g. training phase, workout, facilities, logistical support) a particular approach or combination of heat acclimation regimens and individual heat training sessions can be used to induce adaptations.

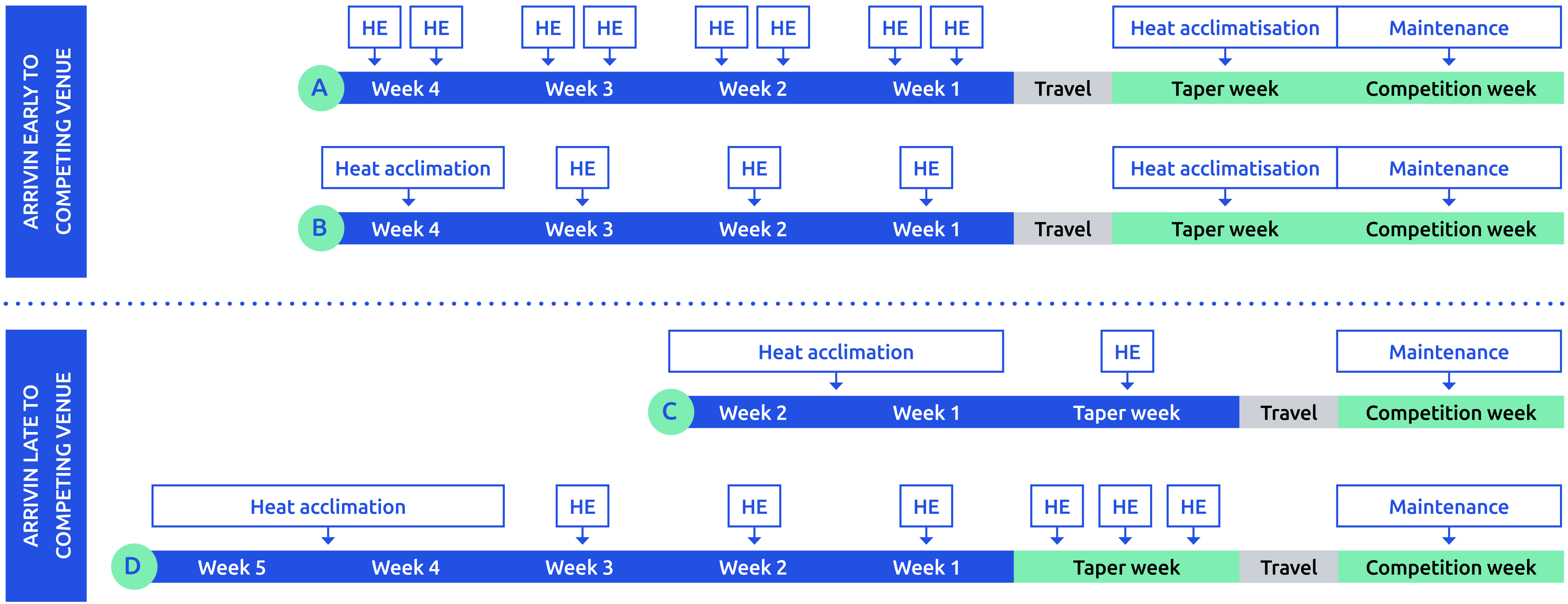


Figure 7:

HE (heat exposure) = Unique exposure conducting non-key workout (e.g. ≥60 min, 40°C & 40% RH), or clamped heat rate protocol (e.g.

85% HRmax, ≥60 min, 40°C & 40% RH), or passive heating post-workout in the cool (e.g. 20-45 min, sauna ~80°C or hot bath 40°C).

Heat acclimation = Daily exposures for 7-14 days of clamped heat rate protocol (e.g. 85% HRmax, ≥60 min, 40°C & 40% RH), or non-key workouts (e.g. ≥60 min, 40°C & 40% RH), or passive heating post-workout in the cool (e.g. 20-45 min, sauna ~80°C or hot bath 40°C).

Heat acclimatisation = Training outdoors at the competition venue in the heat, avoiding the hottest part of the day when doing key workouts. Maintenance = Heat acclimation/acclimatisation adaptations maintained through competing and conducting training sessions in the outdoor heat.

Reproduced with permission from Saunders, Garvican-Lewis [29]

What pre-cooling strategies can I use before a race? What about during the race?

Minimising unnecessary heat exposure and heat gain is advised prior to the start of a race. Athletes should warm-up in the shade if possible and reduce the length of the warm-up.

They might also consider external (ice-vests, cold towels, or fanning) and internal (cold fluid or ice slurry ingestion) pre-cooling strategies, or a combination of both [30]. A practical approach might be to pre-cool in a bath or use commercially available ice-vests during warm-up, which can provide some cooling benefit without affecting optimal muscle temperature and function.

During the event, athletes should wear light-coloured clothing to minimize the effect of the sun's radiation, but clothing should not impair sweat evaporation. In hot and dry conditions, self-dousing with water can provide additional cooling power, whereas other cooling techniques such as ice-slurry ingestion provide more of a perceptual benefit than a cooling effect (due to the small volume ingested when competing). To minimise any disruption to the athlete during competition, any new cooling method should be trialled and individualised in training before the event.

Paratriathletes with a neurological impairment should consider the impact cooling may have on their spasticity pre-race. Furthermore, athletes with a spinal cord injury and lower sensate skin area may not be able to sense excessive cooling and could be at risk of autonomic dysreflexia. It has also been found that if cooling techniques are adopted by athletes with a spinal cord injury, then lower perceptions of thirst and thermal strain may become apparent, resulting in an inadequate fluid replacement strategy [31]. Hence, cooling methods and drinking strategies should be practiced in combination.

How does hydration status influence performance?

Sweat evaporation is the primary avenue of heat loss when exercising in the heat.

As such, profuse sweating can lead to dehydration during prolonged events in the heat if body fluid losses are not sufficiently replaced [32]. Dehydration beyond 2-3% of initial body mass intensifies the rise in whole-body temperature and impairs prolonged exercise performance. This occurs as dehydration negatively impacts on cardiovascular function, making it more difficult to maintain blood pressure and blood flow to the working muscles and the skin (for heat loss). Therefore, being well-hydrated before the start of an event and minimising body mass losses during an event by drinking adequately are important for athletes to perform well and ensure their safety in the heat. Simple techniques such as measuring body mass before and after exercise or evaluating urine colour in the morning (first void) can help athletes assess fluid losses through sweating and estimate hydration status and needs.

For spinal cord-injured athletes, consideration for the catheter bag may be warranted when using the pre- and post-exercise weighing approach. Also, it may be harder to establish hydration status via urine colour, since the use of medications may influence the accuracy of this technique [33].

How much should I drink?

Drinking to thirst is adequate for exercise lasting less than 90min in cool environments. However, a drinking plan or hydration strategy is suggested during activities over 90min, particularly when performed at high intensities producing elevated sweat rates [34].

Hydration strategies should be tailored to each athlete based on sweat rate in conditions similar to that of the upcoming race, in order to prevent body mass losses exceeding 2-3%. This individual prescription must remain within the limits of the how much fluid can be absorbed by the body (~1.2 L/h) and tailored to the availability of fluids on the course.

It is important to recognise that hydration regimens should never result in excessive over-hydration as this can lead to hyponatremia, a serious health issue related to an imbalance of the salts in the body that can be more severe than dehydration and even lead to death.

Athletes with a spinal cord injury that display an impaired sweat response should be aware of the risk of overhydrating and subsequent urinary tract infections. Alternatively, for athletes with an indwelling catheter, it is important to ensure steady hydration across the course of the day to ensure hydration and help flush through the catheter to reduce the risk of urinary tract infections [33].

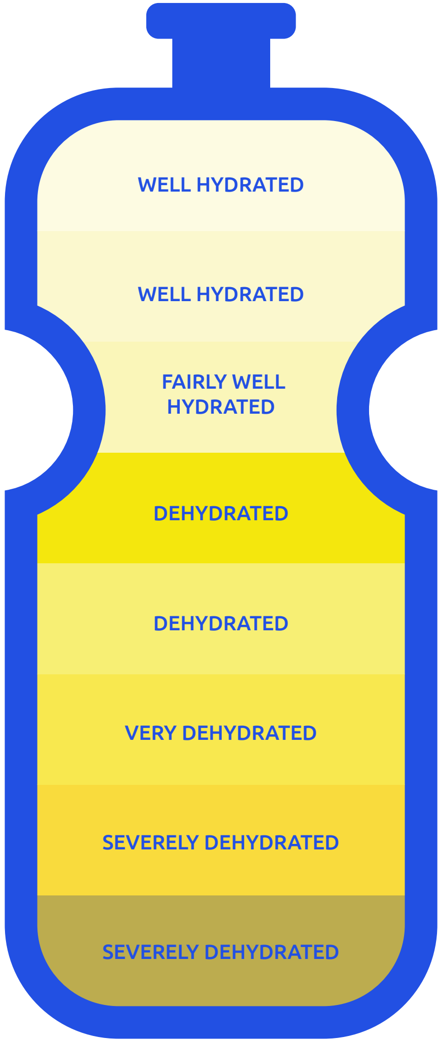


Figure 8:
Urine colour and hydration status

What should I drink?

Sodium (salt) supplementation during exercise lasting longer than 1hr is recommended for heavy and 'salty' sweaters. Sodium intake may be increased before and after hot-weather training and racing. During events, electrolyte tablets or a pinch of salt may be added to the drink bottle of athletes that can tolerate the taste. Including 30–60 g/h of carbohydrates to drinks for exercise lasting longer than 1hr and up to 90g/hr for events lasting over 2.5hrs is advisable.

This can be achieved through a combination of fluids and solid foods. To optimise recovery following training or competing in the heat, body mass losses should be restored within a few hours through the ingestion of recovery drinks that include sodium, carbohydrates, and protein. The preferred method of rehydration is through the consumption of fluids with foods, including salty foods.

From a paratriathlete perspective, it is important to consider the nature of the impairment as this may influence the prevalence of upper gastrointestinal symptoms, which may have an influence on the timing and composition of foods (liquid vs. solid) [33]. There are no disability-specific guidelines at present, so it is recommended that athletes trial the advice noted earlier.

How is environmental heat stress determined?

The severity of the environmental conditions can be estimated by the Wet-Bulb-Globe-Temperature (WBGT) index.

The WBGT is calculated from the dry (standard thermometer) temperature, wet-bulb temperature (indicative of the true capacity of the air to evaporate water according to its relative humidity and air velocity) and black globe temperature (indicative of solar radiation heat load). A WBGT above 32.2°C is considered an extreme risk for experiencing exertional heat illness. The International Triathlon Union uses a hand-held device to calculate the WBGT and a flag system to provide warnings and recommendations to the athletes.

Figure 9:
WBGT monitoring tool and flag warning system

What are the new World Triathlon rules to help mitigate heat stress?

Assessing on-site environmental heat stress at regular intervals using the Wet-Bulb-Globe-Temperature (WBGT) index and providing announcements of its readings. WBGT levels for the modification of exercise or competition for healthy adults are based on recommendation from the American College of Sports Medicine (2007).

The World Triathlon technical director (TD), Medical Delegate, Race Medical Doctor (RMD) and Local Organising Committee (LOC) will work together to monitor the weather conditions. A contingency plan will be implemented in consideration of any extreme meteorological situations that could force the race to be modified (reduce length) or rescheduled.

Any decision made will take into consideration the level of medical assistance, facilities in the medical tent, evolution of the weather conditions and forecast, period of the competitive season, race distance and category, athlete fitness level and the age of the athletes. Event organisers will pay particular attention to unexpected or unseasonably hot weather in mass-participation events, considering that the un-acclimatised participants or participants without a sufficient level of training are at higher risk for heat illness.

During the races, weather information and the WBGT index will be provided at the Sport Information Centre and the Athlete Lounge. The information will be posted in the Athlete Lounge in time for athlete check in. The WBGT index will be converted to a five-level coloured flag system indicating the heat illness risk of current weather conditions. The information will be delivered in the form of written announcement (sample below).

Table 1:

Wet Bulb Globe Temperature (WBGT) Risk Categories (World Triathlon, 2019)

WBGT Risk Categories			Recommendations	
Flag colour	**WBGT Heat index**	**Risk**	**Acclimatized, fit, low-risk triathletes**	**Non-acclimatized, unfit, high-risk individuals**
Black	>32.2°C	Extreme	Re-schedule competition	Re-schedule competition
Red	30.1-32.2°C	Very High	Limit intense competition and total daily exposure to heat and humidity. Watch for early signs and symptoms	Re-schedule competition
Orange	27.9-30.0°C	High	Plan competition with discretion, watch at risk individuals carefully	Limit intense competition. Watch at-risk individuals carefully
Yellow	25.7-27.8°C	Moderate	Normal activity monitor fluid intake	Plan races with discretion, watch at risk individuals carefully
Green	< 25.7°C	Low	Normal activity monitor fluid intake	Normal activity monitor fluid intake

Considering that the World Triathlon has the upper water temperature limits for cancelling the swim, the cycling and running leg require the most attention with regards to heat illness.

Although cycling may provide greater air flow and possibly a greater potential for heat loss than running, athletes may be at risk of exertional heat illness based on the environmental conditions, but also the race tactics and course geography.

When running at a high intensity, a large amount of metabolic energy is released in hot conditions. With a decrease in heat loss capacity relative to cycling, the run leg of the triathlon should be considered the section of the race in which heat illness has the highest likelihood to occur.

In case of a Very High Risk (WGBT index: 30.1-32.2°C, Red Flag) the following will be taken into consideration for Standard and Sprints events:

- Standard distance events: change to Sprint distance
- Sprint distance events and below: stay as originally planned
- If the LOC and Medical Staff are unable to provide medical assistance respecting all the rules of the World Triathlon Event Organizer Manual Medical Services and Exertional Heat Illness Prevention document, particularly in large mass participation events, the competition must be rescheduled.

In case of an Extreme Risk (WGBT index: >32.2°C, Black Flag) the competition must be re-scheduled to its original or shortened distance.

For the Tokyo 2020 Olympic and Paralympic Games, the following heat counter-measures have been put in place:

- Start time moved earlier due to the heat - 6:30 am
- Increase the number of aid/drink stations on the run course
- Establish a cooling station. Tent with fans and air-conditioning
- Athletes may rest in cooling zones but any medical assistance will be DNF
- Trained medical personel will be positioned every 500m on the run course
- Provide ice gel and ice at aid/drink stations
- Coaches are allowed to provide nutrition in designated coaches area on the bike (park) and run course
- Athletes can keep a cooling box/bag in their transition
- Littering zones have been removed (no penalties)
- Road painted with special paint to reduce heat on Field of Play
- For Paratriathletes a fridge car will be used to ensure ice is still cold during the entire race
- Additional shaded areas available for athletes
- Quick medal ceremony and introduction to reduce heat exposure
- Coaches are allowed to place cold or frozen water bottles on to bikes between the end of athletes' introduction and the start of the race
- Athletes can wear cooling vests until their introduction
- Medical marine and heat stress treatment protocols have been reviewed and specially trained personel have been added to the teams.

Check IOC's Athlete 355 platform for more information

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Authored by:

Julien D. Périard (UCRISE),

Ben T. Stephenson (LU),

Vicky L. Goosey-Tolfrey (LU),

Thanos Nikopoulos (World Triathlon), and

Sergio Migliorini (Wolrd Triathlon)

University of Canberra Research Institute
for Sport and Exercise (UCRISE)
Building 29, University of Canberra
Bruce, ACT 2601
Australia

www.canberra.edu.au/research/institutes/ucrise

School of Sport, Exercise and Health Sciences
The Peter Harrison Centre for Disability Sport,
Loughborough University (LU)
Epinal Way, Loughborough
Leicestershire, LE11 3TU
United Kingdom

http://www.lboro.ac.uk/departments/ssehs

https://www.lboro.ac.uk/research/phc/

World Triathlon
Maison du Sport International
Av. de Rhodanie 54
1007 Lausanne
Switzerland

www.triathlon.org

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Contact

Thanos Nikopoulos
Head of Operations World Triathlon
thanos.nikopoulos@triathlon.org

Dr Sergio Migliorini
Chair of World Triathlon Medical Committee
sermigliorini@alice.it