

PRACTICAL RECOMMENDATIONS FOR ENDURANCE CYCLING IN HOT/ HUMID ENVIRONMENTS

– Written by Dave Nichols, Qatar

Road cycling events are frequently held throughout the summer season, often in hot and/or humid conditions. It is well documented that exercise in a warm environment poses a significant thermal challenge to the body and has the potential to reduce exercise performance. The combination of heat production from working muscles and reduction in the rate of heat loss due to high ambient temperatures and/or humidity results in an exacerbated rise in core temperature (hyperthermia) for any given exercise intensity. Hyperthermia per se impairs aerobic performance and consequently decreases power output compared with temperate environments. In

addition, dehydration during exercise in the heat further exacerbates the thermal and cardiovascular strain and further impairs aerobic performance.

Several explanations for the progressive deterioration in performance during exercise in the heat have been proposed, including a reduction in maximal aerobic capacity ($\text{VO}_2 \text{ max}$) and increased physiological demands. In particular, there is a greater cardiovascular strain required to support competing demands for both oxygen delivery to the working skeletal muscle and the skin blood flow requirements for heat dissipation through the processes of conduction and convection¹.

It is also apparent that there is a significant central nervous system component to fatigue when exercising under a high thermal load and that central integration of core temperature, skin temperature and other peripheral inputs also determines an individual's ability to maintain a particular workload in the heat. Further evidence for this assertion has been provided by studies showing that a number of centrally-acting pharmacological agents are able to improve exercise capacity in hot environments, but not in more temperate conditions. There are several relatively simple, non-pharmacological interventions that are also able to influence the central perception of

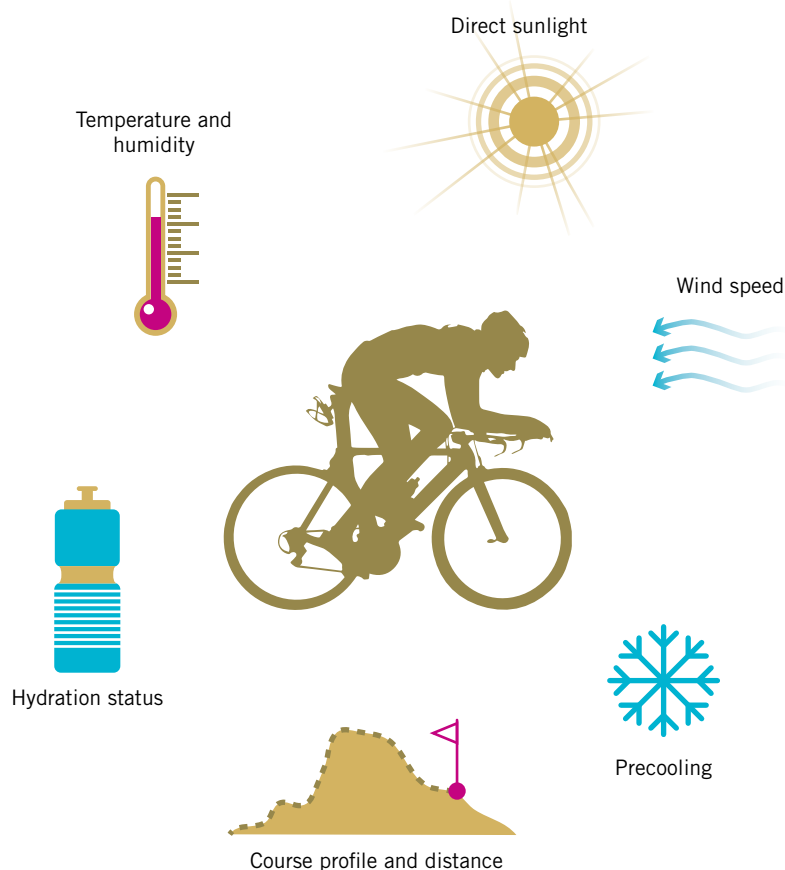


Figure 1: Factors influencing heat strain when cycling in the heat.

fatigue, which will be discussed later in this article.

KNOW YOUR RACE

To optimally prepare for competition in the heat, it is crucial to research the demands of the race and expected weather conditions before and during competition, since any intervention aimed at reducing heat strain should be targeted specifically to that event. Firstly, the nature of the race should be identified, since heat strain is more likely to occur with increasing duration and sustained high-intensity work:

- Prologues or races of shorter duration (under 20 minutes) are less affected by conditions of high heat and/or humidity as they may not be long enough to increase whole-body temperature to levels that can affect performance. However, a very long and intense warm-up can influence performance during a subsequent event. Countermeasures to offset large increases in temperature

- during a warm-up are suggested below.
- Time trials (30 to 75 minutes) are the most likely events to be affected by heat stress. During a long time-trial, high power outputs are maintained for extended time periods resulting in significant metabolic heat production and therefore large increases in core body temperature and skin temperature, as well as sweat loss. As a result, power output will progressively diminish and heart rate will gradually increase for any given power output. During a road race, cycling in the peloton might offer more opportunities to rest and recover compared to an individual time trial. This may attenuate the thermal load as the production of high power outputs will be interspersed with periods of low power output or rest (e.g. during a descent). However, riding in a break-away group and on uphill courses might lead to large increases in thermal load due to the sustained high-intensity

work and the low wind velocity associated with relatively slow climbing speeds.

Environmental factors which affect heat strain include:

- Ambient air temperature
- Relative humidity
- Wind speed
- Solar radiant heat
- Course terrain and associated workload intensity – heat strain is likely to be exacerbated on hilly courses compared to flatter terrain.

Environmental heat stress is most reliably estimated using the wet bulb globe temperature (WBGT) index, which incorporates ambient heat, humidity and solar radiant heat stress from direct sunlight. It is calculated from the following formula: $WBGT = 0.7T_w + 0.2T_g + 0.1T_a$, where: T_w is the natural wet-bulb temperature, T_g is the globe thermometer temperature and T_a is the dry bulb temperature. WBGT is a standardised method to determine climatic conditions and does not take into account the individual response, level of heat acclimation or metabolic heat production and therefore cannot predict heat dissipation. The WBGT can be divided into four zones to assess the potential risk of heat strain and provides a framework for various sporting activities, rather than fixed cut-offs; $<18^{\circ}\text{C}$ low risk, 18 to 23°C moderate risk, 23 to 28°C high risk and $>28^{\circ}\text{C}$ extreme risk. However, these typically apply to non-cycling events, where speed of movement and thus air flow, is lower. It is likely that elite cyclists can tolerate a greater WBGT and so these guidelines may be overly cautious in cycling events. Even so, where events are held with a WBGT above 28°C , athletes should be extra diligent with their hydration and cooling strategies; in some cases the event may be delayed or rescheduled. Notably, the UCI has recently introduced a policy for revising races based on extreme environmental conditions. Figure 1 highlights some of the factors influencing heat strain when cycling in the heat.

HEAT ACCLIMATISATION/ACCLIMATION

The best strategy to prepare for racing in the heat is to heat acclimatise in the same environment as that expected during the

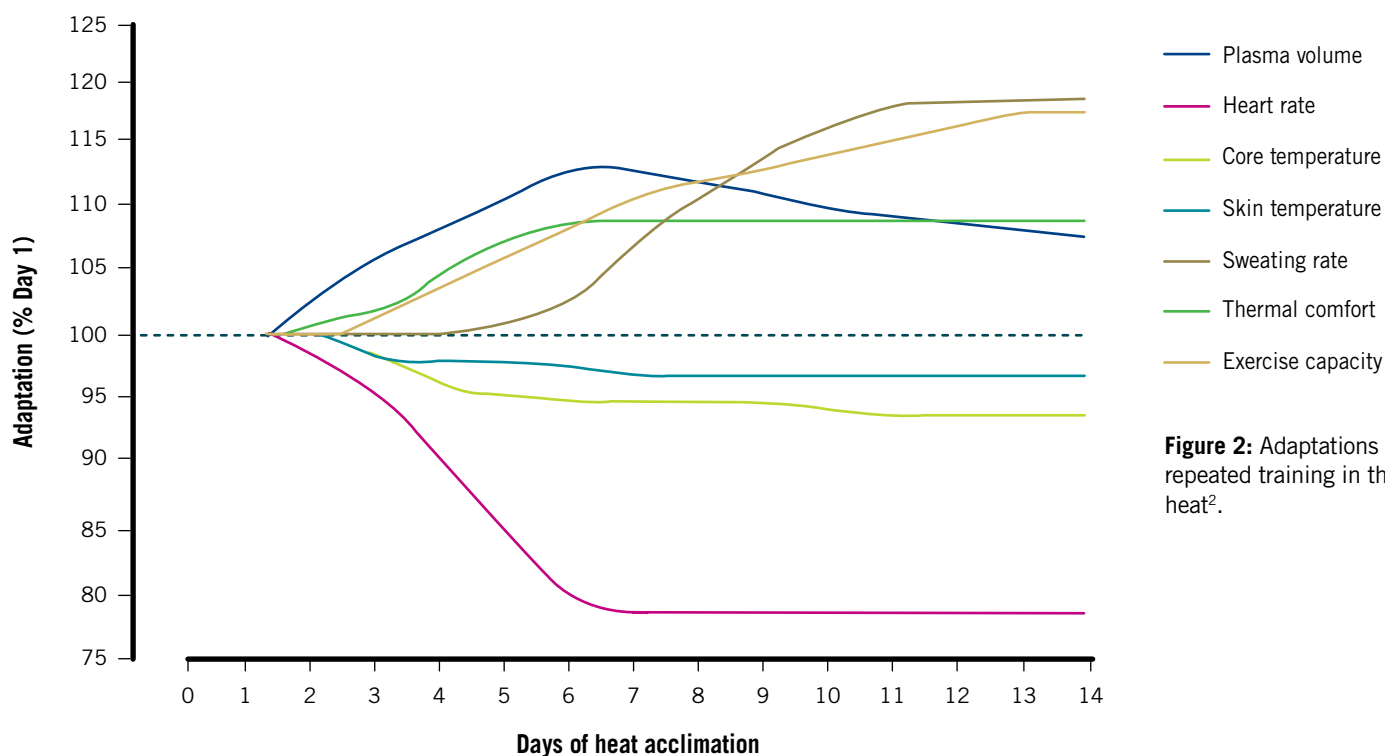


Figure 2: Adaptations to repeated training in the heat².

race. This can be either achieved through acclimatisation (natural heat exposure during outdoor training) or acclimation (simulated heat exposure in an indoor environmental chamber, for example). While some degree of heat acclimatisation is achieved by normal endurance training, even in temperate environments, a far greater magnitude of adaptation can be achieved by repeated exercise in a warm environment. Heat acclimatisation sessions should last a minimum of 60 minutes/day and induce a marked increase in body core and skin temperatures, as well as stimulate sweating². The most visible adaptations of the body to repeated training in the heat include; an increased sweat rate, a decreased heart rate at a given intensity, a better retention of electrolytes and a decreased body core temperature. These adaptations contribute to improved thermal comfort and improved submaximal as well as maximal aerobic exercise performance and minimise the risk of developing heat illness. There are large individual differences between athletes in the rate and magnitude of adaptations related to heat acclimatisation. However, most adaptations develop within 7 to 10 days (Figure 2). As such, it is recommended that cyclists preparing for an event taking place in hot and/or humid conditions train in a similar environment for 2 weeks prior to competition. This

contributes to a marked improvement in cycling time trial performance after the first week and approaching a near complete restoration of performance compared to temperate environments after 2 weeks³ (Figure 3). Conducting an initial heat acclimatisation camp several weeks before the target event may increase the speed at which adaptation occurs in a follow-up pre-competition camp. If it is not possible to train in the same environment as the approaching competition, most adaptations can alternatively be acquired by artificially simulating heat or minimising heat dissipation (e.g. no fan, with heaters) during indoor training. Moreover, an emerging strategy is to use passive heat acclimation techniques such as hot water immersion for 30 to 40 minutes immediately post-training, when core and skin temperatures will already be elevated. The water temperature should be 40 to 43°C (measured with a pool thermometer) to induce adaptation while remaining tolerable. Although these techniques are not as specific as exercise heat acclimatisation per se, they are comparatively convenient and facilitate maintenance of high quality training with heat acclimation simultaneously. Furthermore passive heating strategies can be used prior to travelling to a hot environment and reduce the time required for acclimatisation upon arrival.

FLUID INGESTION

Exercising in the heat causes heavy sweating that can result in dehydration if fluids are not sufficiently replaced. Severe dehydration exacerbates the rise in whole-body temperature and impairs prolonged cycling performance. Dehydration markedly impairs cardiovascular function, mediated by a reduction in blood volume, cardiac output and mean arterial pressure, as well as reducing the ability to tolerate hyperthermia. Therefore, sufficient hydration prior to, during and after exercise is important for athletic performance as well as reducing vulnerability to heat illness.

Athletes should consume adequate fluids in the 24 hours prior to performance to ensure that they are euhydrated. Specifically it is recommended to consume 5 to 7 ml/kg body mass of fluid ~4 hours before and 3 to 5 ml/kg body of fluid ~2 hours before competition⁴. These drinks should contain sodium or salty snacks should be consumed at the same time. During exercise it is recommended that hydration regimens be individualised to each athlete based on sweat rate, to prevent body mass losses exceeding 2 to 3%. It is important to consider that the temperature and flavour of beverages plays an important role in voluntary fluid intake. Specifically, fluids should be cooled in insulated bottles, with additional spares stored in ice boxes in team

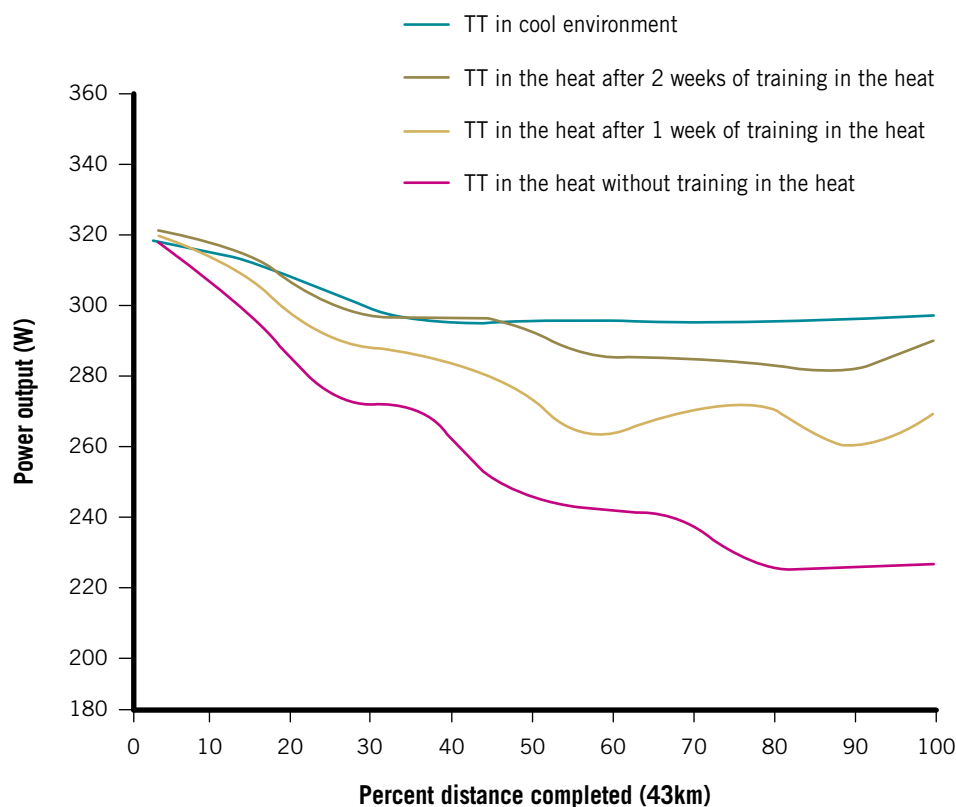


Figure 3: The impact of heat acclimatisation on time trial performance³.

cars to preserve the low fluid temperatures during the race. This individual prescription should remain within the limits of gastro-intestinal absorption rates (~1.2 L/h), to avoid gastro-intestinal discomfort. However, there is on-going debate regarding the level of dehydration at which performance in the heat actually becomes impaired, although the evidence remains equivocal. In some circumstances permissive dehydration particularly towards the latter end of a hilly/mountain race might even be ergogenic, since a 2 to 3% reduction in body mass would equate to a ~2 kg reduction in body mass for a 70 kg cyclist, facilitating faster climbing speeds. Nonetheless, it would be prudent to err on the side of caution and ensure euhydration prior to and during the early parts of the race. Any attempts to manipulate dehydration levels during competition should first be tested in training. It is also important to recognise that hydration regimens should never result in hyper-hydration, as this can lead to hyponatraemia and death in some extreme circumstances. Another consideration would be the need for frequent bathroom stops during a race, which necessitates

increased energy expenditure to regain contact with the peloton.

During exercise lasting longer than 1 hour, it is advisable to consume carbohydrate-electrolyte beverages. Current guidelines suggest including ~60 g/hour of carbohydrates (glucose) in drinks for exercise more than 1 hour, and up to 90 g/hour (glucose + fructose in a 2:1 ratio) for events lasting more than 2.5 hours. This can be achieved through a combination of fluids and solid foods. Drinks should also contain 20 to 50 mmol/L of sodium. While many sports drinks already contain some sodium, if necessary, higher sodium concentrations can be most readily achieved by the addition of commercially available electrolyte tablets to the fluid. Following training or competing in the heat, athletes should aim to rehydrate by consuming 150% of sweat losses (determined by careful weighing immediately pre- and post-exercise), including additional sodium intake. In addition to rehydration, athletes should aim to consume ~1 g/kg/hour body mass of carbohydrates for up to 4 hours for muscle glycogen resynthesis and 20 to 30 g of high-quality protein every 3 to 4

hours for muscle repair and recovery. The addition of protein also enhances fluid retention. Important factors to consider for post-exercise rehydration include; drink palatability, volume, composition and the rate of drinking. Consuming adequate fluid and including carbohydrate, protein and electrolyte sources over several hours post-competition modulates rehydration by slowing the rate of delivery of the drink into the circulation and increases the retention of the drink once it reaches the circulation.

DEHYDRATION MONITORING

Simple techniques such as measuring body mass before and after exercise can help athletes assess fluid loss through sweating and estimate hydration needs and status. In addition, during stage racing or training camps, riders can monitor their morning body mass (post-void) to detect a change in hydration status based on a series of daily measurements. For example, a fall in morning body mass of 2% or more is suggestive of dehydration. Monitoring of urinary indices provides an alternative method. Evaluating urine osmolality and/or urine-specific gravity with commercially available and inexpensive devices, are strong markers of hydration status. Reference ranges typically quoted for euhydration are; <700 mosmol/kg for urine osmolality and >1.020 for urine-specific gravity. However, there is quite marked interindividual variation around these ranges and it may be more appropriate to construct individual reference ranges for each athlete, based on repeated measurements of urine parameters. Z scores can be then be calculated, which denote how extreme an individual reading is, while Reference Change Values can also be used to gauge the degree of change from the previous sample. Only first morning urine samples should be used, to reduce the effect of previous exercise and food intake. The ideal situation is probably to combine serial measurements of body mass with simultaneous assessments of urinary indices.

PRE-COOLING

Immediately prior to competition it is advisable to minimise unnecessary heat exposure and heat gain. Where a warm-



© Tim de Waele/Tim De Waele/Corbis/Getty Images

**Image above:** A portable refractometer.**Image left:** A rider carries water bottles for his teammates.

up is required (for example before a time trial) it should be conducted in the shade and with a large electric fan in front of the rider. Further measures include external (ice-vests, cold towels, facial water spraying) and internal (cold fluid or ice slurry ingestion) pre-cooling methods. Pre-cooling is suggested to improve endurance performance by lowering an athlete's initial core temperature, thereby increasing the heat strain capacity⁵. While the use of commercially available cooling vests is practical, it is likely to yield only a small benefit. Cold water immersion is a very effective tool to lower core temperature, but is impractical and may negatively affect optimal muscle temperature and function. The best approach may be a combination of fanning, ice-cooling vests, cold water and ice slurry ingestion. Additionally, percooling (cooling during exercise), may provide further benefit during racing. This approach is frequently used by professional cyclists by applying 'ice-socks' (often home made by filling women's hosiery with ice) to cool the

neck area and requires team-cars to have cool-boxes or race organisers to provide ice during the race. Anecdotaly, their use can significantly reduce thermal perception when racing in the heat and they are very popular with the professional peloton. Any cooling method should be tested and individualised during training to minimise disruption to the athlete.

EQUIPMENT CHOICES

Equipment choices in cycling should be chosen specifically for the environment. Measurement of WBGT may provide a beneficial tool for informing clothing choices. In environments with high radiant heat (high globe temperature), riders should wear light coloured clothing (white) and avoid black or dark coloured clothing. This is due to the physical characteristics of dark objects tending to absorb light from the sun and subsequently emitting it as heat, while light objects tend to reflect the wavelengths of light and so absorb little. They should also use a non-greasy sunscreen to reduce

radiant heating of the skin, which not only protects the skin from damage, but may also help to marginally reduce skin temperature. Eyes should be protected by wearing UV ray blocking sun-glasses, preferably in a dark tint (i.e. grade 3). Where high humidity is expected, fabrics which promote airflow should be selected to renew a cool boundary layer between the skin and the environment and reduce water vapour pressure to support heat loss through evaporation (sweating). Some cycle apparel manufacturers now produce both jerseys and shorts with mesh panels in order to provide higher rates of airflow. It's important to apply sunscreen to the skin underneath the mesh panels if they are on the rider's back, since the mesh fabric provides less protection from the sun's rays.

Neuropathic foot pain, caused by increased foot pressures secondary to swelling of the feet can occasionally occur during training and competition in the heat. Light coloured shoes (white), with good ventilation and large toe-boxes may help to alleviate these problems.



Saddle (perineal) injuries also seem to be more common when riding in the heat, particularly if the terrain is flat and the rider is spending much of the time riding in the saddle. This may reflect the reduced power outputs that typify exercising in the heat, resulting in reduced peak pedal forces and, subsequently, increased saddle pressures. Alternatively, it may reflect a degree of swelling of the perineal tissues, leading to increased shear and compressive forces on the perineal skin. In order to alleviate such problems it would seem prudent to apply chamois cream to the skin and to use cycling shorts with a high-quality insert (pad).

Given that the temperature of the skin on the face/head has a relatively large influence on thermal perception (this is why athletes often pour water over their heads on a hot day rather than drink it), it is recommended that cyclists opt for well vented helmets to promote optimal airflow and to keep the head as cool as possible. It would also be advisable to choose a light coloured helmet in order to reduce radiant heating. The situation may be a little different during time trials, where a balance must be achieved between airflow and aerodynamic optimisation, which is achieved with a more solid helmet, with fewer vents.

KEY POINTS

- Cyclists should heat acclimate for at least 1 week, but ideally 2 in a similar

environment to that in which they will compete. Sessions should last at least 60 minutes a day and induce a marked increase in body core and skin temperatures, as well as stimulate sweating.

- Adequate fluid and salt should be consumed before, during and after training or competition to ensure euhydration (monitored by body mass and urinary markers).
- Specific countermeasures should be implemented before (pre-cooling: fanning, ice-cooling vests, cold water and ice slurry ingestion) and during (percooling: 'ice socks') competition to reduce heat storage and physiological and perceptual strain.
- Light coloured apparel (helmet, jersey, shorts and shoes) which promotes airflow should be selected over dark coloured, aerodynamic kit (time trials maybe an exception to this).

References

1. Sawka MN, Leon LR, Montain SJ, Sanna LA. Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. *Compr Physiol* 2011; 1:1883-1928.
2. Racinais S, Alonso JM, Coutts AJ, Flouris

AD, Girard O, González-Alonso J et al. Consensus Recommendations on Training and Competing in the Heat. *Sports Med* 2015; 45:925-938

3. Racinais S, Périard JD, Karlsen A, Nybo L. Effect of heat and heat acclimatization on cycling time trial performance and pacing. *Med Sci Sport Exerc* 2015; 47:601-606.
4. American College of Sports Medicine, Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, et al. American College of Sports Medicine position stand. Exercise and fluid replacement. *Med Sci Sports Exerc* 2007; 39:377-390.
5. Bongers CC, Thijssen DH, Veltmeijer MT, Hopman MT, Eijssvogels TM. Precooling and percooling (cooling during exercise) both improve performance in the heat: a meta-analytical review. *Br J Sports Med* 2015; 49:377-384.

Dave Nichols M.Sc.
Postgraduate Researcher
Ph.D. Candidate
Aspetar – Orthopaedic and Sports
Medicine Hospital
Doha, Qatar

Contact: David.nichols@aspetar.com