



Marathon runner Sviatlana Kudzelich cools down during an event in Doha.

## The heat is on

As global temperatures rise, athletes and sports bodies are following the science to ensure that events can take place safely. **By Sarah O'Meara**

**W**hen Scottish distance runner Callum Hawkins collapsed in the 30°C heat of Australia's Gold Coast while leading the marathon at the 2018 Commonwealth Games, he was left on the roadside for several minutes before paramedics came to his aid.

A delay of a few minutes might seem slight, but if heat exhaustion is not treated rapidly it can have dire consequences. Just a few months later, American football player Jordan McNair died as a result of heatstroke sustained during practice at the University of Maryland in College Park. An investigation revealed that staff at the university waited more than an hour before calling an ambulance, during which time they failed to adequately cool his body.

The challenges associated with exercising in extreme environments have been studied since at least the 1930s, says Paul Hough, a sports scientist at St Mary's University in Twickenham, UK. For many years, athletes

not used to competing in hot conditions have trained in warmer climates to acclimatize and reduce the risk of heat illness. Over time, strategies have been refined in the laboratory to offer more precise and evidence-based advice. "What the last 30 years of sports-science research has done is to better understand the physiological and psychological mechanisms at play," Hough says.

Despite this progress, heat is only becoming more of an issue in sport, says Sébastien Racinais, head of research at Aspetar, an orthopaedic and sports-medicine hospital in Doha, Qatar. Climate change is bringing more frequent and longer spells of hot weather, and hot regions such as the Persian Gulf and East Asia are playing host to international sporting events more regularly. The next Olympic Games, scheduled to take place in Tokyo in July, could be the hottest on record, Racinais says. More effective and personalized heat-acclimatization strategies are important.

But event organizers must also take steps to minimise heat exposure and provide rapid care when necessary.

### Heat-proof tailoring

For someone who knows the dangers, it can be scary to watch people competing in extreme heat – often regarded as temperatures of more than 30°C. "You just want to watch them get safely over the line," says Laura Needham, a physiologist at the English Institute of Sport in Manchester, UK. She has been developing strategies to help British triathlon athletes withstand the expected heat of Tokyo since before the 2016 Rio de Janeiro Olympics. The aim is to force the body into short-term physiological changes that make the athlete less prone to premature fatigue, diminished performance and heat illness. Research in this area has tripled over the past two decades, and is built on techniques first developed to help soldiers fight in hot climates.

A decade ago, the approach to acclimatization was not especially rigorous, says Oliver Gibson, an exercise physiologist at Brunel University London. Athletes would either travel to warm-weather training camps or spend time exercising in environmental chambers tuned to recreate a certain temperature and relative humidity. In either case, the focus was simply on the time they spent in the heat, with little thought to optimizing how the body adapted.

But in the past 5–10 years, he says, researchers have refined the techniques. During a process called controlled hyperthermia, scientists encourage athletes to do 30 minutes of exercise to raise their core temperature to around 38.5°C – a degree beyond the normal healthy range. They then maintain that temperature for another 30–60 minutes, either by sitting in a sauna or continued gentle exercise.

Over a series of sessions, commonly spread across 5–10 days, athletes can undergo a number of physiological adaptations, including increased sweat rate, lowered heart rate, improved comfort during exercise and a lowered resting core body temperature.

The key to making acclimatization work, however, is personalizing the programme to an athlete's natural response to high temperatures, says Needham. Although heat illness generally sets in when body temperature reaches around 40°C, the temperature at which physical performance begins to suffer differs from person to person. "We learn what our athletes' thresholds are and how their bodies regulate this rise," says Needham.

Such tailoring is especially important for female athletes. In a study that compared men and women, researchers found that women generally took longer to physiologically adapt

to heat than men (N. V. Kirby *et al. Front. Physiol.* <https://doi.org/10.3389/fphys.2019.00539>; 2019). This suggests that a training programme that works for men might not provide adequate protection for everyone else.

Ahead of Rio 2016, Irish runner Sara Treacy did 2 sets of acclimatization training at 32°C and 80% relative humidity over 5 and 7 days in an environmental chamber at the University of Birmingham, UK. Ollie Armstrong, a sports scientist at the university who oversaw Treacy's training, says that this was more than he would typically plan for a male athlete because he wanted to ensure her body could fully adapt.

### Time to cool

The other big challenge for athletes and coaches is finding time to put the theories of acclimatization into practice, says Lee Taylor, a sports scientist at Loughborough University, UK. But athletes are making acclimatization more of a priority. In 2015, just 15% of competitors at the World Athletics Championships in Beijing reported that they had completed a dedicated acclimatization period of 5–30 days (J. D. Périard *et al. Br. J. Sports Med.* **51**, 264–271; 2017). At the 2019 competition in Doha, Racinais says that more than half had done so.

Over the past five years, more athletes have been implementing less demanding measures, such as bathing in hot water and using the sauna after training, says Gibson. These still encourage heat adaptation, but interrupt an athlete's training programme much less.

Not all athletes are taking steps to better manage heat, however. During the Doha championship, Canadian race walker Evan Dunfee says he was shocked by how few athletes took an ice bath, which can lower core body temperature and reduce the adverse effects of heat, before competing. "For our 50 kilometre race, there were only 5 or 6 of us using them," he says. Nearly half the field failed to finish, and almost all of those who pre-cooled finished above their ranking, he adds.

### Too much to ask?

While many athletes try to get better at dealing with heat, organizers of events are taking steps to reduce the heat stress athletes are exposed to. Increasingly, sports bodies are adjusting the timings of competitions so that they are held at cooler times of the day or year, as well as stipulating the conditions under which competitions will be moderated or suspended.

For example, Needham says that during a test event for the women's triathlon in Tokyo in August 2019, the conditions – as determined by wet-bulb globe temperature, which takes into account ambient temperature, relative humidity, wind and solar radiation – exceeded



Runner Callum Hawkins after collapsing in 30°C heat during a marathon in Australia.

the safety limit. As a result, the competitors ran half the planned 10 kilometre distance.

Organizers are also putting in place measures to ensure athletes are cared for properly if they are overwhelmed by the heat. Sports scientist Yuri Hosokawa at Waseda University, Tokyo, who sits on a panel tasked by the International Olympic Committee with mitigating weather-related risks to athletes and spectators, says nothing is more important in a heat emergency than cooling a person. Research suggests that immersing athletes up to their neck in 10°C water can cool them effectively. "We need to cool an athlete for around 15 minutes, until their rectal temperature is below 39°C, before moving them," Hosokawa says.

But many health-care professionals working with athletes might never have come across a situation in which they had to use cold-water immersion, says Hosokawa. It might contradict what they have been taught about what to do in an emergency, such as getting the person to the hospital as quickly as possible, she adds.

A lack of readiness to offer cold-water immersion was one of a number of problems identified in a report into the death of McNair. When medical staff took him from the field, they did not use cold-water immersion to cool him because they were concerned he could drown in the bath, owing to the relatively small stature of those providing care. Instead, they applied cold towels. When he arrived at the hospital around two hours after he started to show symptoms, his body temperature was still 41°C. The University of Maryland accepted responsibility for its role in McNair's death and agreed a US\$3.5 million settlement with his family in January.

All venues at the Tokyo Olympics holding high-risk heat events will have access to water baths, and training will be given to health-care providers to ensure athletes are safe, Hosokawa says. But in the future, event organizers might be able to manage athletes' safety even more closely.

In 2015, health-device manufacturer Bodycap in Hérouville Saint-Clair, France, demonstrated a telemetric pill that can track a person's core body temperature without them having to wear a monitor – opening the door to tracking temperature during competitions. So far, researchers have used the pill in a handful of studies.

Racinais thinks that this raises questions about how real-time data about a person's well-being should be used. "If we can see an athlete is getting unhealthily hot, such as 41°C and above, should we intervene? These are the kinds of questions we'll be asking," he says.

When a global television audience watched Hawkins lying on the roadside for several minutes without help, many were angry that paramedics did not attend to him sooner. But, speaking to UK broadcaster the BBC after the event, Hawkins said he was reluctant to accept help that would end his race. "As a competitive elite athlete, I'm always going to say 'no,'" he said. "I just wanted to keep pushing."

"Trainers have a duty of care," says Needham. "But in the end, it's always an athlete's choice whether to compete." All she and other sports scientists can do is make sure athletes are as ready as they can be.

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