**Training tips/health snippets**

**The science of running in the heat**

**Body temperature and heat removal**

Why is running harder when it’s hot out? It all comes down to thermal regulation, as demonstrated in a widely-cited 1999 study by José González-Alonso and his co-workers at the August Krogh Institute in Denmark.

The researchers conducted two separate experiments examining different aspects of heat regulation: body temperature and heat removal.  In the first experiment, seven cyclists performed a ride to exhaustion at a predetermined effort in a hot laboratory.  Before the ride, the cyclists were either “pre-heated” or “pre-cooled” in water baths for 30 minutes.  The experiment was repeated three times, so each cyclist had started a trial with a body temperature of 96 °F (pre-cooled), 98 °F (control: no bath), and 100 °F (pre-heated).  The cyclists then rode at 60% of their maximum effort (as monitored by oxygen intake) until exhaustion; all while having their internal temperature measured using a probe in their throat (positioned there so as to be close to the brain).

As we might expect, the **pre-heated cyclists did the worst, followed by the control group, and finally the pre-cooled cyclists, who were able to bike the longest**.  Interestingly, they all became exhausted at nearly the same internal temperature: about 104 °F.

In the follow-up study described in the same paper,1 four cyclists (who were not pre-heated or cooled) cycled another trial to exhaustion in the heat while wearing specially-made jackets which had a large volume of water (either hot or cold) pumped through them continuously.  These jackets either increased or decreased the rate of heat removal from the athlete’s core.

Again, as we might expect, the **subjects who were cooled by their jacket lasted significantly longer than the subjects who were heated**.  But again, whenever they reached 104 °F, the riders elected to stop.

So it seems that the drop in performance associated with exercising in the heat is a form of “central” fatigue.  That is, it’s not so much that the muscles themselves are getting tired prematurely; the body is actively moderating the rate of exercise when it starts to get too hot, probably to protect the brain from thermal damage. But people don’t (usually) suddenly stop running because of the heat—they just slow down.  What’s going on there?

### How does the body control heat build-up during exercise – and what happens

Important differences happen in a time-trial setting (as opposed to a work-to-exhaustion setting), as highlighted by a 2004 study by Tucker et al.2  His study examined cyclists completing a 20km time trial in a lab either at 95 °F or 59 °F.

Predictably, the hot conditions resulted in slower times and higher internal temperatures.  Peak internal temperature was the highest at the end of the ride, reaching 100 °F in the cool condition and 102 °F in the hot condition.  But, most revealing was the pacing: the subjects in the hot time trial went slower from the start.  The authors interpreted this as showing that **the body has an “anticipatory” strategy for controlling heat build-up—that is, your performance is impaired even before you reach a “critical temperature**.”

This conclusion has been criticized because Tucker et al. measured rectal temperature, not esophageal temperature (which apparently can fluctuate more rapidly than core temperature, and is better correlated with brain temperature), but regardless, it proves an important thing for us: **working out in the heat is not inherently dangerous, provided you listen to your body**.  The current theory is that, in most cases, the brain will pace the body (or just force you to give up) to stay within an acceptable heat range, and that cases of heat exhaustion and heat stroke are a failure of this mechanism (which occurs for reasons unknown as of yet).

### How long does it take to adapt to running in the heat

That leaves us with one topic unexplored: adaptation.  One of the reasons you’ve probably been feeling the heat recently is the fact that you haven’t been exercising in hot weather for several months.  It’s well-demonstrated that adapted runners handle the heat better, mostly by getting their heat-regulating mechanism like sweating up and running sooner.  But how long does it take to get adapted to the heat?

A 2008 study by Sandström et al. addressed this issue by monitoring changes in an ultra-marathoner’s blood during a 15-day heat adaptation period prior to a race.  The researchers used heat shock protein 70, a blood marker that correlates with heat adaptation.  The ultra-marathoner had his blood tested every day of the 15-day taper.  The results showed an initial boost in protein levels during the first five days of the taper, followed by a flat period of a few days, and then a slower, steady increase through the end of the study.

Since Hsp70 levels were still increasing, the researchers concluded their study wasn’t long enough! **Full heat adaptation appears to take upwards of two weeks, even though there’s a strong response in the first few days**.

Now, this study was only done with one subject, so your own adaptation pattern may vary, and we’ll have to wait on further studies using this method of measuring heat adaptation.

## What you can learn from the science

We’ve seen that heat can be a significant detriment to your performance.  No matter which way you look at it, the body does not do well when its core temperature increases past a certain point.

* While it’s reasonably safe to go for a run or line up for a race even when it’s hot out, you also need to listen to your body and be honest with yourself. You’re not going to be able to run the same pace when its 85 degrees out that you can when it’s 65. To help you determine [how much the heat will effect your running performance](http://runnersconnect.net/training/tools/temperature-calculator/), we’ve created a [simple calculator for you](http://runnersconnect.net/training/tools/temperature-calculator/).
* As you’ve undoubtedly been told, staying hydrated is a critical component to keeping the body cool and replenishing the water and electrolytes you sweat out. To make determining your hydration needs easier, we’ve created this simple [sweat loss calculator for runners](http://runnersconnect.net/training/tools/sweat-loss-calculator/). For more tips on when and what to hydrate with, you can also read our [summer hydration article](http://runnersconnect.net/running-nutrition-articles/summer-hydration/).
* If you’re a runner who sweats excessively or who has major issues running in the heat, you can also try a technique called “[hyper-hydration](http://runnersconnect.net/running-nutrition-articles/hydration-for-running-glycerol/)“. Hyper-hydration involves using nutritional supplements to store extra water, which will help keep you hydrated longer should you be a heavy sweater.
* González-Alonso’s two studies give us a clue as to how to overcome the heat too: try to stay cool for as long as possible! [Pre-cooling before a race or hard workout](http://runnersconnect.net/running-injury-prevention/running-in-the-heat-pre-cooling/) is a scientifically proven method to help improve performance in the heat. My college coach used to have the team douse ourselves in ice-water before the start of a hot race—you can do this too as a low-tech alternative to González-Alonso’s water-cooling jacket and “pre-cooling” baths.
* You can also probably curtail your warm-up a bit on hotter days, since you don’t want to elevate your core temperature prematurely. You can try implementing a dynamic warm-up such as a lunge series or active isolated stretching, which take less energy, but still loosen up your running muscles. You can find these routines as part of our [strength training for runners](http://runnersconnect.net/strength-training-for-runners/) guide.
* Finally, you can take comfort in the fact that, while heat adaptation may take a period of several weeks, early evidence indicates that you’ll see a strong boost in adaptation within five days or so of exercising in hot weather.