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FRONT MATTER EDITORIAL

To drink or to pour: How should athletes use water to cool themselves?

It's almost that time again. With the 2016 summer Olympics in Rio just around the corner, the season of dreams is upon us. It's the time when we watch seemingly real life super heroes push themselves to the limit, while bringing back early memories of when we wanted to be those athletes on TV that children look up to. At the Rio games, not only will these super humans compete against each other, they must also contend with the hot and balmy conditions.[1] Some of us, during sporting activities, may be familiar with battling against our own minds and dealing with the oppressive force of the heat, when we would happily accept any measure that alleviates the discomfort of our exertions. With respect to endurance sports in the heat, this relief can come with sipping cool water, spraying our face with a cool mist, or wrapping an ice towel around our necks.

The cover photo of this edition of *Temperature* illustrates a scenario of two elite triathletes, Andrea Hewitt (on the left) and Rachel Klamer (on the right), dousing themselves with water from their bottles in order to cope with both the internal heat they are producing through muscular contractions, and the external heat from the surrounding environment. We sometimes see athletes self-dousing with water, or have done it ourselves, in order to attain an immediate relief from the heat rather than taking the time to drink. But is this a smart move? Shouldn't we just drink the water instead, or even better – drink iced water?

To answer this question, we must consider how much heat we can lose to water in its various forms. The most straightforward way is to do so via conduction following the ingestion of cold water. The amount of heat lost is determined by the temperature difference between the ingested water and the body core, the volume of water drunk, and the specific heat capacity of water, i.e. the amount of heat energy needed to warm up 1 g of water by 1°C, which is 4.184 J/g/°C. We can dramatically increase the amount of heat lost to water by adding ice into the mix, as the amount of heat required to melt ice, known as the latent heat of fusion, is much greater than the specific heat capacity of water at 334 J/g. It is this much greater potential for heat loss that has led to the recent trend of athletes consuming ice slurry drinks, a mixture of shredded ice and water, before or during their athletic activities. Despite this improved potential for heat dissipation, melting ice is still a far cry from the amount of heat we can lose through the evaporation of water, as just one gram of evaporated water results in the liberation of a massive 2430 J of latent heat energy.

To put these different cooling strategies into context, we can directly compare heat loss potential with a fixed volume of water (Fig. 1). Assuming a core body temperature of 38°C, drinking one glass (250 ml) of 1°C water would result in a net heat loss of 39 kJ. Whereas if the contents of that glass were changed to half-water and half-ice, the potential for heat loss would more than double to 81 kJ. However, if we could somehow spread that 250 ml of water across our skin surface so that it all evaporated, the resultant heat loss would be a whopping 607 kJ. One caveat is that, while it is relatively easy to ingest water without spilling it, ensuring 250 ml of water is distributed across the skin in a way that it all evaporates is much more difficult. However, it is important to keep in mind that if just 15% of that water evaporates from the skin, the heat loss would still be greater than ingesting the entire 250 ml ice slurry.

Another consideration is that the exercise modality and environment in which we perform exercise may alter the effectiveness of dousing ourselves with water, based on how likely the water is to evaporate. For example, dry air and high wind speeds greatly favor evaporation, so cycling in the desert may be an ideal situation for self-dousing with water, as most of it is likely to evaporate. Conversely, high levels of ambient humidity and low air

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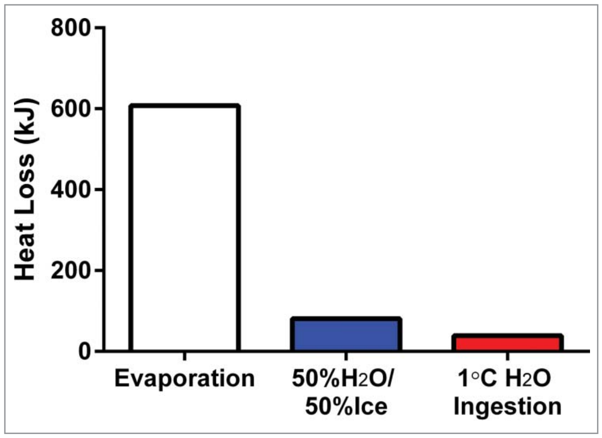

Figure 1. The theoretical maximal amount of heat loss to a fixed amount of 250 ml of water applied as a cooling agent in 3 different ways (from left to right): 1) evaporated from the skin surface, assuming 100% was evaporated, 2) lost to the ingestion of a half-water, half-ice mixture, and 3) lost to the ingestion of 1°C water.

speeds make it increasingly difficult for evaporation to occur, and may just result in a soggy and hot athlete; therefore self-dousing with water may not the best method while jogging in a tropical climate.

Assuming we are jogging in the tropics though, is cold fluid ingestion now a good idea? Perhaps not. After reading multiple studies in which ingested cold fluid did not apparently affect or minimally affected core temperature (see reference[6] for a comprehensive review), we examined local sweating activity as well as core and skin temperature with cold fluid ingestion during exercise.[3] Immediately following cold fluid ingestion, we observed a sudden drop in local sweat rates at all 3 sites measured: the back, forehead and forearm, all of which remained depressed for several minutes (Fig. 2), despite the fact that core temperature and skin temperature were unaltered throughout. Upon further investigation by administering aliquots of water of equal volume and temperature to

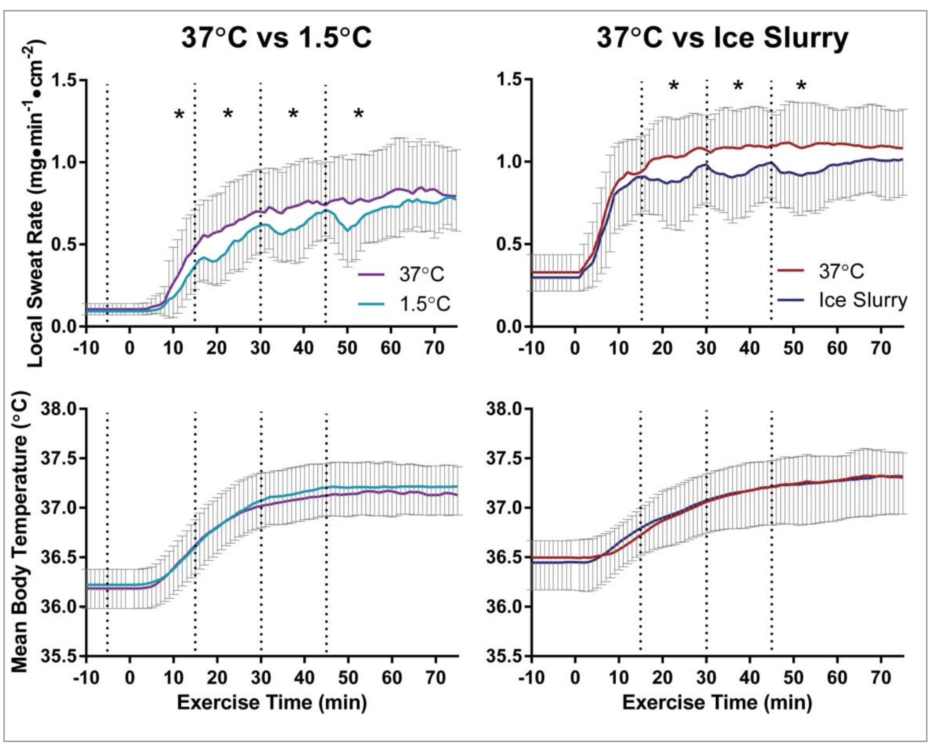

Figure 2. Redrawn from Morris et al. 2014[3] and Morris et al. 2016.[4] Mean local sweat rates (top panels) and mean body temperatures (bottom panels) with 1.5°C water ingestion (left panels) and ice slurry ingestion (right panels). Dashed lines denote time points when fluids were ingested. *denotes where cold fluids are significantly lower than 37°C control fluids ($P < 0.05$).

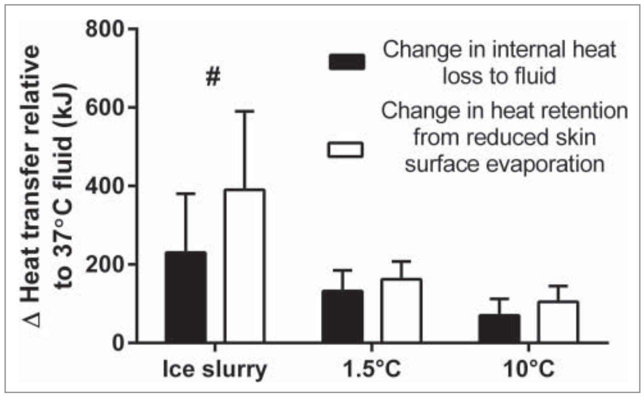

Figure 3. Combined data from Bain et al. 2012[2] and Morris et al. 2016.[4] Black bars denote the amount of heat lost to the ingested fluids relative to the 37°C fluid and white bars denote the amount of heat that was retained due to reductions in sweating relative to the 37°C fluid. # denotes where heat gained from the fluids is greater than the heat lost to sweating ($P < 0.05$).

the mouth via swilling or directly into the stomach via a nasogastric tube, it was determined the reductions in sweating were due to signaling from independent thermoreceptors probably located in the stomach and/or small intestine without input from thermoreceptors located in the deep body core or skin.[3] Further, we conducted a subsequent study examining ice slurry ingestion during exercise and found similar results, with sweating drastically reduced following ingestion again without changes in core or skin temperatures.[4]

More important than just the changes in local sweat rate, however, we also carefully measured environmental parameters, such as air velocity, ambient temperature and humidity, and designed the experiment so we could accurately estimate heat loss from all avenues of heat transfer. Critically, alterations in evaporative potential due to differences in sweating were determined.[2] We found that compared to a 37°C drink, the reduction in evaporative heat loss with 1.5°C and 10°C fluid ingestion was approximately equal to the additional internal heat transfer obtained with these drinks (Fig. 3). Even more surprising was that in the follow up study during which participants ingested ice slurry drinks,[4] the reduction in sweating compared to a 37°C drink was so great that it actually exceeded the internal heat transfer to the ice slurry – despite the extra internal heat loss due to the latent heat fusion. As such, ice slurry ingestion led to a greater, not smaller, net heat storage compared to a 37°C drink (Fig. 3). It must be acknowledged though that a distinct advantage of ingesting cold fluids is that all internal heat transfer is 100% efficient, whereas reductions in sweating in a hot-humid environment may not mean that evaporation will be equally impacted. After all, sweat must evaporate to provide a cooling effect, and if it is simply sweat that will ultimately drip off the body anyway that is reduced then cold fluid ingestion will likely confer an advantage.

One last point to consider is that cold fluid ingestion does improve exercise performance and feelings of thermal comfort independently of any differences in core and skin temperatures.[5] But to the best of our knowledge, the effect of self-dousing with water to improve performance has not yet been studied, likely due to the mess that would ensue.

To return to our original question: which is better, to drink or to pour water on yourself? In our opinion, if you are thirsty or if it makes you feel great, go ahead and drink your water, but if you're looking to cool down, feel free to toss your water – on yourself.

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