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FRONT MATTER: EDITORIAL

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From science to practice: Development of a thermally-insulated ice slushy dispensing bottle that helps athletes "keep their cool" in hot temperatures

Like many of us, I love sport. I care deeply about athlete performance. It is my job to. That passion has enabled me to wear a number of hats in the arena. I've been an athlete (triathlon and cycling), a coach, a professor, and an applied sport scientist. Residing in this sometimes messy, often fun, middle-space, between research, theory and application, which do not always align, I've been able to make some observations, identify some problems, and foster some solutions. The topic of this editorial is a story about how I've assisted to bridge a small gap between science and practice, by mixing scientific understanding and ingenuity to alter athlete temperature.

Last year I delivered two presentations in Paris on this topic, entitled: Keeping your cool: How fluid temperature affects thermal comfort and performance in the heat. My opening slide included the picture, shown as Figure 1. Here we have two of today's world-best triathletes, Andrea Hewitt and Rachel Klamer, racing in the Gold Coast World Series Race in Australia (April 2015). In this race, it was 28°Celsius, with high humidity. To me, this picture speaks volumes about what's really important when maximizing performance in hot environments.

Consider the following question: what's essential to these athletes when they have cold fluid in their hands? Are they thirsty and dehydrated, or is it more likely that their brain/body is overheating? If these athletes were thirsty, and fluid consumption mattered to their brain at that point, then surely they would be more interested in drinking that fluid; but clearly they are not. When it's on, with metabolic heat production sky high, (as it is in most of the Olympic sports we deal with) it's brain temperature, or perhaps more accurately the brain's recognition of a body that's overheating that matters.[1]

So let's go back in time a bit and allow me to tell you the story about how I became involved in discovering the importance of fluid temperature for performance in the heat. While employed as a lecturer at Edith Cowen University (ECU) in Perth Australia, I enjoyed collaborating with Dr David Martin, an Australian Institute of Sport Senior Physiologist, in the area of precooling athletes before competition in the heat in order to improve performance.

It was 2006, and the Beijing Olympics were at the forefront of our minds. We'd put our heads together previously for the Athens' Games strategy where we had arrived at the position that the best precooling strategy possible, was a combining a plunge pool maneuver with an ice jacket to retain body coolness.[2] Beijing, expected to be just as hot, was up next, and we were still searching for something effective and practical to keep athletes cool.

Meanwhile, a sport scientist up in Darwin, named Matt Brearly, was doing some experimentation during his bike rides. Of course, it doesn't get much hotter in Australia than this place. Very simply, he was looking at what happened to his performance times riding home from work when he drank cold fluids vs. ice slushy. Ice slushy is the mix of solid ice particles and a bit of glucose to serve as an antifreeze, inside a water medium to form a slurry. Matt was finding a big difference to his performance times in the heat, going much faster when he drank the ice slushy before his ride. Now why would that be?

To understand, we need to dig deeper. With phase change, any energy required to reconfigure a substance from a solid to a liquid water gets transferred from the area of concern. In a person ingesting the ice slushy, that's the person themself. So in theory, even if the substances were at the same temperature (0°C), the solid

Color versions of one or more of the figures in this article can be found online at www.tandfonline.com/ktmp.

Figure 1. Elite triathletes Andrea Hewitt (left) and Rachel Klamer (right) competing in the International Triathlon Union World Triathlon Series event on the Gold Coast of Australia (April 2015) in hot conditions (28°C, 70% humidity). © International Triathlon Union/Delly Carr. Reproduced by permission of International Triathlon Union/Delly Carr. Permission to reuse must be obtained from the rightsholder.

ice component of ice slushy would make you cooler than the liquid water due to that phase change energy component.[1]

Great in theory, but it needed to be tested. Would it really work? To begin, we did a very simple study; similar to what Matt did in Darwin. We wanted to investigate what happened to run time to exhaustion in the heat if we ingested cold water or ice slushy beforehand? Here, doctoral student at the time, Rod Siegel, showed us that the ingestion of ~500 g of ice slushy in the 30 min period prior allowed subjects to run an average of 10 min longer (20%) compared with drinking a 4°C solution of the same volume (Fig. 2; see also ref. 3). Sounds simple now, but I remember being fascinated at the time, as I experienced the effect myself as one of the subjects. I didn't feel as hot, and hard exercise felt easier.

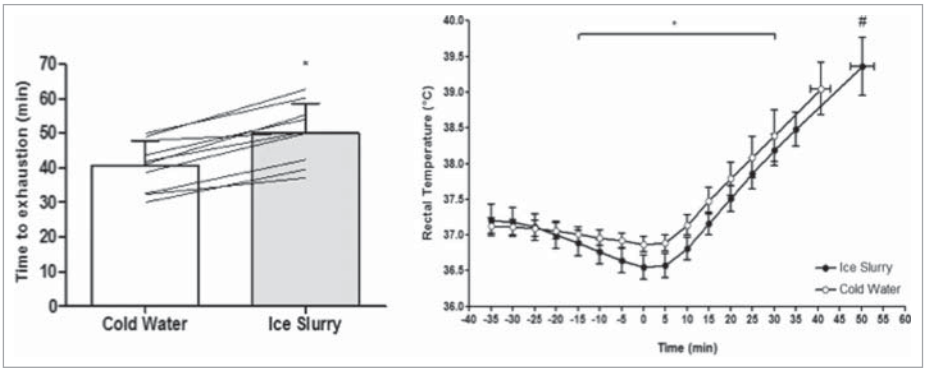

Figure 2. Redrawn figures from Siegel et al.,[3] showing mean ± SD run time to exhaustion (left panel) and rectal temperature (right panel) response to running at aerobic threshold in 34°C (55% relative humidity) after drinking ice slushy (−1°C) versus cold fluid (4°C). Lines denote individual data (n = 10). Time to exhaustion was longer (*) after ice slushy compared to cold water ingestion (P = 0.001), and rectal temperature was lower (*) with ice slurry compared with cold water ingestion from the 20-min time point of drink ingestion until 30 min of exercise (P<0 .05). At exhaustion however, rectal temperature was greater (#) after ice slurry ingestion (P = 0.001).

Figure 3. Prototype bottle developed by the 4th year Engineering students at the University of Canterbury. Pictures owned by the author.

The second most interesting finding for me was the consistent elevation of core (rectal) temperature above the control condition. The data was flying in the face of the critical core temperature hypothesis; that is, we all have this set point of temperature that we can reach, but it doesn't go any higher. So why was ice slushy ingestion allowing rectal temperature to get higher? Simply due to the proximity of where it was being measured – rectally – it suggested to us that it is more likely that brain temperature, or the brain's interpretation of body temperature, that is paramount when performance matters in the heat. Meanwhile, another group replicated our finding in field conditions in the Singapore heat.[4]

Fast forward to 2010. Working for the sport of Triathlon at High Performance Sport New Zealand, I pondered the concept that perhaps precooling with ice slushy might improve run performance in hot conditions. Before I even had the chance to test this myself, Chris Stevens, a triathlete and sport scientist from Australia, proved the concept and showed improved run times in the heat following ice slushy ingestion during the cycle phase of a simulated Olympic distance triathlon.[5] Problem was, while Stevens et al.[5] nicely proved the concept in the lab, application in the field wasn't as easy. Existing bottles did not contain spouts that allowed the flow of ice slushy to the user. A solution was needed, and was achieved through a 4th year engineering student program out of the University of Canterbury in Christchurch, NZ. Here, a group of engineering students took on the problem and came up with an elegant solution (Fig. 3).

Once the concept was proven, we tested the bottles with a group of elite triathletes. While they enjoyed the ice slushy on hot days, the reality was that the bottle was cumbersome and it leaked. A commercial solution was clearly needed. This was achieved by transferring the intellectual property out of High Performance Sport New Zealand into Teknicool Limited, a New Zealand corporation, that created a product for commercial sale (Fig. 4). High performance athletes and teams around the world can now access and use the invention.

The journey from scientific understanding to application has not been without challenges, but the learning has been rich. As scientists continue to search for ways to help athletes keep their cool, watch for more refinements and innovation in this space.

Figure 4. Phase 2 commercial bottle developed for market by Teknicool Ltd. © Teknicool Ltd. Reproduced by permission of Teknicool Ltd. Permission to reuse must be obtained from the rightsholder.

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