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The effect of ice slurry ingestion on body temperature and cycling performance in competitive athletes

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ABSTRACT

The effects of pre cooling on endurance performance are widely known. In contrast, the approach of cooling during endurance exercise in combination with pre-exercise cooling has been poorly understood. The purpose of the present study was to determine whether the effects of precooling and cooling during exercise enhance exercise performance compared to the ingestion of a thermo-neutral beverage (20 °C) or precooling alone in cycling performance. This was an experimental study using a randomised crossover design in which 7 cyclists underwent three trials comprising of 45 min steady state cycling (SS) at 70% VO_2 max and a subsequent 10 km time trial (TT) in hot conditions (32 °C, 50% relative humidity). Rectal temperature (T_{re}), heat storage (HS), heart rate (HR), blood lactate concentration (BLA) and thermal sensation (TS) were measured. The intervention consisted of: (1) ingestion of thermo-neutral beverage before and during SS cycling (TN), (2) ingestion of ice slurry beverage and application of iced towels (precooling) prior to exercise, and then ingestion of thermo-neutral beverage during SS (PRE) and (3) precooling strategy as above plus ice slurry ingestion during SS cycling (PRE + MID). The intake of thermo-neutral or ice slurry beverage (14 g/kg) occurred over 30 min before and every 15 min during SS cycling. There was no significant difference in TT performance between all the conditions ($P = 0.72$). However, PRE and PRE + MID caused a significant decrease in T_{re} ($P < 0.05$) from TN during exercise. Accordingly, both precooling and a combination of precooling and mid-cooling during exercise in hot conditions may be a practical and effective way of reducing core temperature. Future studies should investigate longer distance events and timing of ice slurry ingestion.

1. Introduction

Athletes experience thermoregulatory strain during exercise in a hot and humid environment, leading to decreased central neurological drive and reduced skeletal muscle activation (Nybo et al., 2014; Ament et al., 2009; Morris et al., 2016). Excess generated body heat must be dissipated in order to maintain homeostasis during exercise in thermoneutral or hot conditions (Ament and Verkerke, 2009). Two strategies to reduce core temperature include pre-cooling and cooling the body during exercise (mid-cooling). Reducing initial temperature gives the body an increased capacity to store metabolic and environmental heat (Noakes, 2000; Ross et al., 2013). Pre-cooling may produce a heat 'sink', allowing the athlete to exercise for longer before reaching a high core temperature that may be associated with reduced exercise intensity or the cessation of exercising altogether (~40 ⁰C) (Nielsen et al., 1993). Moreover, mid-cooling may allow for continual maintenance and/or enhancement of the positive effects associated with pre-cooling for endurance performance in hot conditions (Burdon et al., 2013a, 2013b; Tyler et al., 2015). Cooling the body using external devices (i.e.cooling jackets, cold-water immersion, cold-air exposure) presents practicality issues for athletes in the field, whereas, ice slurry ingestion and iced-towels may present an accessible alternative to these methods (Lee et al., 2008).

Ice slurry ingestion is an effective pre-cooling strategy for reducing rectal (Siegel and Laursen, 2012), gastrointestinal (Ihsan et al., 2010), skin temperatures (Siegel et al., 2010), and improving exercise performance (Stevens et al., 2016a, 2016b; Maunder et al., 2017). It further assists nutrient (carbohydrate and electrolytes) delivery and sustains hydration status. However, Morris et al. (2016) recently expressed reservation regarding ice slurry ingestion since it may lead to a lower net

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heat loss during exercise in warm conditions. Moreover, an improvement in exercise performance has not always been consistently demonstrated. This is the case of Stevens et al. (2016a, 2016b) when measuring effects with runners using two different techniques; menthol mouth rinse and ice slurry ingestion. The lacking effect of ice slurry may be a consequence of a shorter exercise protocol inducing lower levels of heat stress, as previous studies that also reported no improvements Levels et al. (2013) with slightly shorter protocols.

Fewer studies have been conducted examining the effect of a combination of pre and mid-cooling (Stevens et al., 2017). Some studies have demonstrated improved endurance performance using the combination method (Tran Trong et al., 2015) whereas others have reported no benefit (Schultze et al., 2015). Furthermore, Stevens et al., 2017 reported no added benefit of pre-cooling in addition to mid-cooling in isolation for short duration endurance performance. Therefore, further research is required to elucidate the effect of a combined approach to cooling for the enhancement of performance in hot conditions. The aim of the study was to assess the effectiveness of a combined approach of pre- and mid-cooling upon cycling performance in hot conditions. Therefore, we hypothesised that a combined approach of pre-cooling and ice slurry ingestion during exercise, will improve cycle time trial performance in the heat compared to consumption of a thermo-neutral drink.

2. Methods

2.1. Participants

Seven well trained and unacclimatized, male road cyclists (age 34.7 ± 6.3 y, height 178.6 ± 6.7 cm, weight 77.1 ± 8.4 kg, VO_2max 59.54 ± 6.7 ml/kg/min) volunteered to participate in the study. The participants were accustomed to prolonged and intensified exercise in training and competition with a minimum of seven years of cycling competition experience. All of them participated in national events in Australia during the year of study and two of them participated in international championships. Prior to the experiment, participants underwent a health screening questionnaire that identified any contra-indications to exercise. This ensured that participants were free of injury or illness and had no prior history of heat stress. Participants were provided written informed consent documents before participating and were able to withdraw at any time. The study was approved by the University of Adelaide Human Research Ethics Committee and performed according to the Helsinki Declaration.

2.2. Preliminary measures

Body mass (in cycling shorts) was measured to the nearest 0.1 kg using an electronic floor scale (Tanita, Tokyo, Japan). VO_{2max} was determined by a maximal incremental exercise test to exhaustion on a cycle ergometer (Wattbike, Nottingham, UK). The test comprised 3 min stages and commenced at a workload of 1.5 W/kg of body mass, and increased by 30 W at the completion of each stage. The test was terminated when the participant could no longer maintain the required workload or reported volitional exhaustion. Pulmonary ventilation (VE), oxygen uptake (VO_2) and carbon dioxide production (VCO_2) were recorded through a fully automated indirect calorimetry system (K4b2, Cosmed, Rome, Italy).

2.3. Experimental design

Participants attended four separate sessions: a preliminary and three experimental trials. Participants were allocated an order of experimental trials in a randomised crossover design. Trials were (1) thermo-neutral trial with no cooling before or during exercise (TN), (2) pre-cooling before exercise (PRE), or (3) pre-cooling and mid-cooling during exercise (PRE + MID). Before each trial participants undertook a 15 min warm up at 1.5 W/kg in temperate conditions (23 °C, 50% relative humidity). The experimental trials took place in hot conditions (32°C, 50% relative humidity) within an environmental controlled chamber. Participants exercised on a cycle ergometer (Wattbike, Nottingham, UK) at 70% VO_{2max} steady state (SS) for 45 min, followed by a 10 km time trial (TT), using self-selected cadence and intensity (see Fig. 1). The only information available to participants during the TT was the distance covered (m). Participants maintained and recorded regular training commitments during the period and were asked to refrain from exercise during the preceding 24 h of each session.

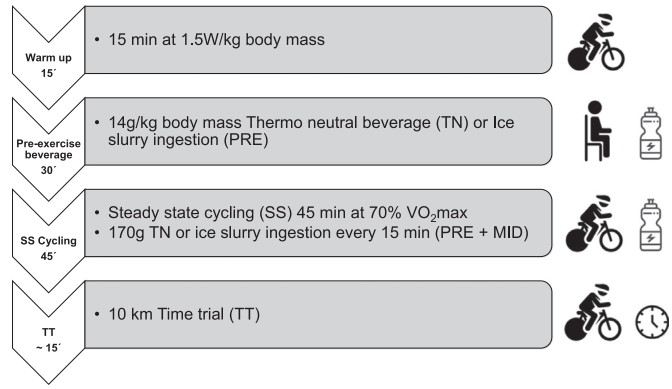

Fig. 1. Design for the three experimental trials.

2.4. Cooling methods

The pre-cooling procedure followed the protocol outlined by Ross et al. (2011). This involved the ingestion of ice slurry (−1 °C) made from a commercially available 7.4% carbohydrate-electrolyte sports beverage (Powerade Isotonic, Coca-Cola Amatil, Australia) at 14 g/kg of body mass in combination with the application of iced towels to the torso in the half hour before cycling. Cooling during exercise involved the ingestion of ice slurry while cycling. The amount and timing for ingestion was modelled on the study by Burdon et al. (2013a, 2013b) in which participants consumed 260 ± 38 g of ice slurry made from sports beverage every 15 min throughout steady state cycling. Participants during the TN trial ingested an identical quantity of sports beverage (14 g/kg) at 20°C as the PRE and PRE + MID protocols to ensure total fluid consumption and carbohydrate ingestion was the same across all trials. This acted as a control to observe the physiological responses associated with sports beverage ingestion without imposing a heat load or deficit.

2.5. Physiological and exercise performance measures

Ambient temperature (°C) and relative humidity (%) were monitored using an electronic thermometer with a hygrometer (TA298, Chengdu, China) during each trial. Before and after each trial participants (in cycling shorts) were weighed and total body water (%) assessed using an electronic floor scale (Tanita, Tokyo, Japan). Physiological measures were recorded every 5 min during the half hour before cycling, every 15 min during SS cycling, and every 5 min during the TT. Participants self-inserted a rectal probe thermometer (Monatherm Thermistor, Covidien, USA) to 10 cm past the anal sphincter. The rectal probe was attached to a temperature monitor (DUOTEMP Fisher and Paykel Healthcare, Oakland, New Zealand) for measurement of rectal temperature (T_{re}). Heat storage (HS) was calculated by $HS = 0.965 \times m \times \Delta T_b/A_D$, where 0.965 is the specific heat storage capacity of the body (W kg^{-1} °C), m the mean body mass (kg), and A_D is body surface area (m^2) ($A_D = 0.202m^{0.425} \times \text{Height}^{0.725}$) (Du Bois and Du Bois, 1989; Adams et al., 1992). A chest strap and corresponding heart rate monitor were secured to measure heart rate (HR)