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Chapter 4

Effect of warm-up and pre-cooling on pacing during a 15-km cycling time trial in the heat

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ABSTRACT

Purpose
The best way to apply pre-cooling for endurance exercise in the heat is still unclear. We analyzed the effect of different preparation regimens on pacing during a 15-km cycling time trial in the heat.

Methods
Ten male participants completed four 15-km cycling time trials (30°C), preceded by different preparation regimes: 10 min cycling (WARM-UP), 30 min scalp cooling of which 10 min was cycling (SC+WARM-UP), ice slurry ingestion (ICE), and ice slurry ingestion + 30 min scalp cooling (SC+ICE).

Results
No differences were observed in finish time and mean power output, although power output was lower for WARM-UP than for SC+ICE during km 13–14 (17 ± 16 and 19 ± 14 W, respectively) and for ICE during km 13 (16 ± 16 W). Rectal temperature at the start of the time trial was lower for both ICE conditions (36.7°C) than both WARM-UP conditions (37.1°C) and remained lower during the first part of the trial. Skin temperature and thermal sensation were lower at the start for SC+ICE.

Conclusion
The preparation regimen providing the lowest body-heat content and sensation of coolness at the start (SC+ICE) was most beneficial for pacing during the latter stages of the time trial, although overall performance did not differ.
INTRODUCTION

Athletes generally perform active warm-up to prepare for an upcoming event. This is proposed to induce beneficial physiological responses (Gray and Nimmo 2001; Hajoglou et al. 2005; Proske et al. 1993; Ross et al. 2001). However, warm-up also elevates the core temperature, causing fatigue and reduced endurance performance in the heat (Duffield et al. 2010; Gonzalez-Alonso et al. 1999; Uckert and Joch 2007). Pre-cooling may attenuate this detrimental effect by increasing the heat-storage capacity of the body and is therefore suggested to be a more beneficial preparation regimen than warm-up (Uckert and Joch 2007).

Ice slurry ingestion appears to be an effective and practical method to pre-cool the body core (Ihsan et al. 2010; Ross et al. 2011; Siegel et al. 2010). The lower core temperature resulting from ice slurry ingestion may prevent or delay the reduction in central neural drive that leads to performance decrements in the heat (Nybo and Nielsen 2001a).

Next to cooling the core, cooling the skin could also affect performance (Ihsan et al. 2010; Nybo and Nielsen 2001a; Ross et al. 2011; Schlader et al. 2011a; Siegel et al. 2010). Recently, a new convective cooling method for reducing chemotherapy-induced hair loss has become available, using glycol-perfused caps to cool the skin of the scalp. Possible mechanisms include a positive effect on the perception of coolness, motivation to continue exercise, and reduction of cardiovascular and thermoregulatory demands. The scalp may be a suitable cooling area, as it is easily accessible (Tikuisis et al. 2001) and close to the thermosensitive region of the face. In addition, possible brain cooling may help maintain the central neural drive during exercise in the heat (Ansley et al. 2008). Both the sensation of coolness and possible brain cooling might translate into an improvement in self-paced exercise performance mediated by the RPE, even when core temperatures are well below critical values associated with fatigue (Ely et al. 2010).
Although both warm-up and pre-cooling have proved to be beneficial for endurance-exercise performance, it remains unclear which preparation regimen should be preferred for relatively short self-paced endurance exercise in the heat. Furthermore, the additive effect of scalp cooling when the core is cooled or heated remains unclear. Therefore, the main goal of this study was to investigate the effect of different preparation regimens (involving warm-up, ice slurry ingestion, and scalp cooling) on pacing and performance during a 15-km cycling time trial (TT) in the heat.

**METHODS**

**Participants**

Ten healthy and physically active male recreational cyclists (age: 24 ± 5 years, height: 187 ± 7 cm, body mass: 77 ± 6 kg) familiar with cycle-ergometer testing participated in this study. The study was approved by the ethics committee of TNO, The Netherlands.

**Overview**

Participants visited the laboratory five times. On the first visit they were familiarized with the experimental setup and distance of the TT. The 4 following sessions involved the 15-km TT in the heat preceded by one of the different preparation regimens: active warm-up of 10 minutes of cycling (WARM-UP), scalp cooling + active warm-up of 10 minutes of cycling (SC+WARM-UP), ice slurry ingestion (ICE), or scalp cooling + ice slurry ingestion (SC+ICE).

**Interventions**

In the pre-cooling trials (ICE and SC+ICE), a decrease in core temperature was created by ingesting 2 g·kg⁻¹ BM ice slurry within five minutes. Syrup (containing approximately 6 g carbohydrates) was added for flavor. This period was followed by 15 minutes of rest. In the pre-warming trials (WARM-UP and SC+WARM-UP), the participants cycled at a moderate power of 2 W·kg⁻¹ BM for 10 minutes. SC was accomplished by wearing a
neoprene-covered silicone cooling cap (Paxman, Huddersfield, UK) connected to a cooling machine (Paxman cooler PScalpC-1, Paxman, Huddersfield, UK) for 30 minutes. Temperature of the coolant was –9°C to –10°C.

**Protocol**

Each session started in a 22°C climatic chamber (Weiss Enet, Tiel, The Netherlands) with 20-minute habituation, followed by baseline measurements and the intervention protocol. Subsequently, during a 5-minute break, participants were transferred to an adjacent 30°C, 50% RH climatic chamber. This was followed by a short final preparation period of 3-minute cycling at 120 W. Hereafter, participants performed the 15-km TT on a cycle ergometer (Lode, Groningen, The Netherlands). During the trial participants were blind to performance measures but were informed of completed distance each kilometer. The four TTs were allocated in balanced order and at least three days apart.

**Measurements**

During the time trials, PO was recorded every second. Rectal temperature ($T_{re}$) was measured every second using a rectal thermistor (Yellow Springs Instruments 700 series, Yellow Springs, OH, USA) inserted 10 cm beyond the anal sphincter. A weighted average of eight iButtons (DS1922L, Maxim Integrated Products Inc, Sunnyvale, CA, USA) resulted in 10-second values for mean skin temperature ($\bar{T}_{sk}$), as described by ISO 9886 (ISO9886-2004). Heart rate was recorded at 5-second intervals (Polar Electro, Finland). For the TT, data were reduced to 1-km values. Thermal sensation and thermal comfort were measured every 5 km on a 9-point and 5-point scale, respectively (ISO10551 1993). RPE was measured every kilometer on a 20-point scale (Borg 1982).

**Statistics**

Experimental condition was the independent variable, whereas PO, $T_{re}$, $\bar{T}_{sk}$, heart rate, RPE, thermal sensation and thermal comfort were the dependent variables. Significance of effects over time was determined using two-way ANOVAs for repeated measurements with Bonferroni correction (SPSS 17.0, SPSS Inc, Chicago, IL, USA). One-way ANOVAs were
used to determine the significance of effects of the experimental conditions at separate kilometers, as well as on finish times and average PO. Statistical significance was set at 5%. Values are reported as mean ± SD.

RESULTS

Effect of Preparation Regimens

In Figure 4.1, T_{re} and T_{sk} before and during the TT are shown. Before the start of the intervention, T_{re} and T_{sk} were similar. Ice slurry ingestion resulted in a cooler core at the start of the TT than performing a warm-up (P<0.05). There was a trend that T_{re} was more reduced in SC+ICE than in ICE (P=0.06). At the start of the TT, both T_{sk} and thermal sensation were lower for SC+ICE than for the other conditions (P<0.05), whereas thermal comfort was similar.

Time-Trial Performance

In Figure 4.2a, the average PO per kilometer of the TT is shown. There was no overall effect between conditions on PO and finish time. However, during kilometers 13 and 14, PO for SC+ICE (231 ± 23 and 239 ± 24 W, respectively) was higher than for WARM-UP (214 ± 28, P=0.01, and 219 ± 27 W, P=0.02, respectively). In addition PO for ICE (230 ± 32 W) was higher than for WARM-UP during kilometer 13 (P=0.03).
Physiological and Perceptual Responses

Differences in $T_{re}$ and $\bar{T}_{sk}$ between the ice slurry and warming-up conditions were observed during the first half of the trial ($P<0.05$). Overall, $T_{sk}$ was lower for SC+ICE than for WARM-UP ($P=0.02$). Heart rate for WARM-UP was higher than for SC+ICE and ICE.
during the initial stages of the trial, but no differences were found after 3 km. No overall effect for RPE was observed, but at separate kilometers in the final stages of the TT, some RPE scores deviated (Figure 4.2b). No effects for thermal sensation and thermal comfort were observed during the trial.

Figure 4.2 Power output (a) and RPE (b) during the time trial. * Difference between warm-up and scalp cooling (SC) + ice slurry ingestion (ICE) (P<0.05). # Difference between warm-up and ICE (P<0.05). † Difference between warm-up and SC+ICE (P<0.05). For clarity of the figure, no error bars are displayed.
DISCUSSION

This study showed that the lower the body temperature and sensation of coolness at the start of the TT, the more beneficial it was for the pacing profile at the final stages. This finding agrees with previous pre-cooling experiments on longer cycling trials (40–90 min), showing physiological differences in the first part of the trial and pacing adjustments at the final stages (Duffield et al. 2010; Ihsan et al. 2010). However, we did not find an overall effect on performance, which is in contrast to the referenced studies. Although direct comparison is difficult due to methodological differences, it appears that exercise duration is important for obtaining overall performance benefits from pre-cooling. Nevertheless, a higher work rate near the finish as a result of pre-cooling may still be beneficial during tactical races. Pre-cooling the core with ice slurry ingestion appeared to be more effective in accomplishing pacing benefits than pre-cooling the scalp. Scalp pre-cooling led to a marginal decrease in thermal strain and a slightly cooler sensation at the start of the TT, but pacing and performance benefits during the trial were negligible. The limited physiological effects of scalp cooling may be due to the insulative capacity of the skull (Xu et al. 1999) and the small cooling area. The absence of a perceptual effect on performance confirms the results of Barwood et al. (2012), who found no effect of thermal perception on the anticipatory selection of PO. RPE differed during the final stages of the TT. The higher RPE for WARM-UP was accompanied by a lower PO than with SC+ICE. This finding seems to disagree with the concept that athletes maintain a similar RPE template across conditions of similar duration and adjust their work rate accordingly (Tucker and Noakes 2009). Carbohydrate ingestion via syrup might be considered a confounding factor. However, it is unlikely that the ingestion of only 6 g carbohydrates 20 minutes before medium-duration aerobic exercise (< 45 min) improves performance in the final stages by extending body glycogen content (Burke et al. 2011) or by non-metabolic pathways (Rollo and Williams 2011).
CONCLUSION

The preparation regimen providing the lowest body-heat content and sensation of coolness at the start of the TT (ICE+SCALP) appeared to be most beneficial for pacing in the latter stages. However, overall performance was not improved after pre-cooling, possibly because of the limited trial length.
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