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Original research

Impact of upper body precooling during warm-up on subsequent time trial paced cycling in the heat

Charles P. Katica[a,*], Jonathan E. Wingo[b], Robert L. Herron[b], Greg A. Ryan[c], Stacy H. Bishop[d], Mark Richardson[b]

[a] Pacific Lutheran University, United States
[b] The University of Alabama, United States
[c] Georgia Southern University, United States
[d] University of Montevallo, United States

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ABSTRACT

Objectives: The purpose of this study was to test the hypothesis that cooling the upper body during a warm-up enhances performance during a subsequent 16.1-km simulated cycling time trial in a hot environment.
Design: Counterbalanced, repeated measures design.
Methods: Eight trained, male cyclists (peak oxygen uptake = $57.8 \pm 5.0\,\text{mL}\,\text{kg}^{-1}\,\text{min}^{-1}$) completed two simulated 16.1-km time trials in a hot environment ($35.0 \pm 0.5\,^{\circ}$C, 43.8 ± 2.0% relative humidity) each separated by 72 h. Treatments were counterbalanced; participants warmed up for 20 min while either wearing head and neck ice wraps and an ice vest (COOLING) or no cooling apparatus (CONTROL).
Results: Following the warm-up mean skin temperature ($\bar{T}_{sk}$), mean body temperature ($\bar{T}_b$) and rating of thermal comfort were significantly lower than baseline following the COOLING trial (all $P < 0.05$); however, rectal temperature was unaffected ($P = 0.35$). Because the effects of precooling on $\bar{T}_{sk}$ and $\bar{T}_b$ were not sustained during exercise, values for COOLING and CONTROL were not different throughout the time trial ($P = 0.38$). Nonetheless, time to completion was significantly faster following the COOLING intervention when compared to the CONTROL (29.3 ± 3.6 min, vs. 30.3 ± 3.1 min; $P = 0.04$).
Conclusions: These data suggest that in short distance time trials in hot conditions cyclists may benefit from utilizing a cooling modality during the warm-up.

1. Introduction

Competitive cycling results in a rise in core temperature due to the high rate of skeletal muscle metabolism and concomitant heat storage.[1–3] Cycling events often take place during the hot summer months, thereby imparing athletes' thermoregulatory capacity and contributing to increased heat storage and a subsequent rise in core temperature.[4,5] Exercise capacity and performance are impaired in hot conditions compared to more temperate ones,[6–8] which may be related to achievement of high core and skin temperatures[5,9,10] and accompanying excessive cardiovascular strain,[11] which will diminish exercise capacity and performance.

Additionally, researchers have demonstrated that performance decrements may be related to high hypothalamic temperature more than high body temperature.[12,13] Therefore, cooling the blood which supplies the hypothalamus may attenuate the rise towards a potentially detrimental, elevated hypothalamic temperature. Furthermore, skin cooling may also increase heat storage capacity thereby preventing a rise in core temperature and hypothalamic temperature that contributes to a decreased aerobic exercise performance in the heat.

Combined, the effects outlined above may explain the efficacy of precooling prior to endurance exercise bouts in hot conditions.[14,17,18] Precooling prior to exercise improves performance and delays fatigue during vigorous intensity exercise in the heat lasting ≈15–40 min.[1,16,17] External precooling strategies include the application of ice packs to the torso and neck[2,7,19] and immersion in water[17,20,21] for ≈20–30 min before exercise. Neck cooling using gel ice wraps and torso cooling using an ice vest are practical and fairly inexpensive precoolings implements and are typically administered during passive rest.[7,22, 23]

* Corresponding author.
E-mail address: katicacp@plu.edu (C.P. Katica).

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Surprisingly, limited research has investigated the effects of precooling during an active warm-up even though anecdotally, many athletes consider a proper warm-up an important way to optimize neuromuscular function and psychological mind set.[1,2] Empirically, an active warm-up has been shown to facilitate rates of muscle contraction.[24] Only two studies have investigated the effect of precooling during an active warm-up before running. Both studies showed that ice vest precooling administered during a warm-up blunted rises in core temperature and heart rate, decreased time to completion, and lowered perceptual measures during the exercise when compared to a non cooling control treatment.[1,24] Extrapolation of the data to activities other than 5-km running is tenuous, however. For example, cycling time trials require more time, utilize a different muscle recruitment pattern, and involve a greater degree of heat loss or gain via convection—depending on the air to skin temperature gradient—than a 5-km running race, and therefore the effects of precooling on cycling events remain speculative and uncertain. Therefore, the purpose of this study was to evaluate the impact of precooling the upper-body during an active warm-up on performance during a simulated 16.1-km cycling time trial. We hypothesized that combined torso and head/neck cooling would result in improved performance (e.g., faster time) compared to no cooling (CONTROL).

2. Methods

A repeated measures research design was used in which all participants were tested under both experimental conditions, which were completed in counterbalanced order. Each of three visits were held at the same time of day, in the mid- to late afternoon to avoid circadian variations in core body temperature. During the first visit participants completed a peak oxygen uptake ($\dot{V}O_{2peak}$) test and a familiarization trial. Then, two 16.1-km simulated cycling time trials were completed in counterbalanced order. Each time trial was preceded by a 20-min warm-up including either (1) head and neck wrapped in gel ice packs and torso covered in an ice vest (COOLING), or (2) no cooling (CONTROL).

Eight active male cyclists and triathletes volunteered to participate (mean ± SD age = 25 ± 3, weight = 78.1 ± 8.6 kg, height = 1.82 ± 0.08 m, body fat = 11.8 ± 2.6%, and $\dot{V}O_{2peak}$ = 50.2 ± 7.2 mL kg^{-1} min^{-1}). An a priori power analysis[25] revealed this sample size was adequate to detect a moderate effect size[26] between treatments for time to complete the 16.1-km cycling time trial. All participants were competitive cyclists & triathletes, free of any known diseases as determined by a health history questionnaire and performing at least 180 km of cycling every week. The study was approved by the university's institutional review board in advance, and participants provided written informed consent prior to participation.

On the first visit, participants completed height and weight (bike shorts only) measurements and body fat percentage estimated from the sum of three skinfolds.[27] Next, they entered an environmental chamber maintained at 22.1 ± 0.2 °C, 35.4 ± 3.0% relative humidity and completed a graded exercise test on an electronically-braked cycle ergometer (Velotron Dynafit Pro cycle ergometer, Racer Mate Inc., Seattle, WA) to elicit $\dot{V}O_{2peak}$. The $\dot{V}O_{2peak}$ assessment consisted of a 5-min warm-up at a self-selected, moderate workload. The test commenced at the same workload used for the warm-up, and power output increased 25 W every two min until volitional fatigue. Oxygen uptake and other gas exchange measures were measured using open-circuit spirometry (Parvo Medics, Sandy, Utah) and were averaged every 30 s. Heart rate (HR) was recorded during the final 10 s of every minute of the GXT using a heart rate monitor (model FT7, Polar, Stamford, CT). Rating of perceived exertion (RPE) was recorded during the final 30 s of each stage.[28] Peak HR was defined as the highest 5-s value observed at volitional fatigue, and peak power output and $\dot{V}O_{2peak}$ were defined as the highest power output and $\dot{V}O_2$ values, respectively, observed over the final 30-s period at volitional fatigue. After a 10-min rest period, participants completed a familiarization trial in the same environment as the graded exercise test in order to become familiar with the experimental testing protocol.

Following a 72-h rest period, participants revisited the laboratory having refrained from vigorous exercise, ingestion of caffeine, and ingestion of alcohol during the preceding 24 h. Upon arrival, a urine sample was collected and urine specific gravity (USG) was used as an index of euhydration (USG ≤1.020). Next, participants dressed in bike shorts, socks, cycling shoes, and a cycling jersey. The same ensemble was worn for each experimental trial. They then inserted a flexible rectal thermocouple (model RET-1, Physitemp, Clifton, NJ) approximately 10 cm past the anal sphincter. The rectal probe was securely taped to the gluteus maximus under the waist band of the shorts. Next, thermocouples were taped to the lateral calf, anterior thigh, lower back, lower abdomen, upper chest and upper back (all on the right side of the body) for measurement of mean skin temperature ($\bar{T}_{sk}$) using the weighted average of the six sites.[29] Participants also wore a HR monitor as described previously. Prior to the start of exercise, each participant was fitted to the cycle ergometer (proper seat and handle bar height, etc.), and they were required to stay seated throughout the duration of the test.

After entering an environmental chamber maintained at 35.0 ± 0.5 °C, 43.8 ± 2.0% relative humidity, participants warmed up for 20 min at 65% $\dot{V}O_{2peak}$ and 70–80 revolutions per minute (RPM). During the warmup, each participants $\dot{V}O_2$ was assessed to verify they were warming up at 65% $\dot{V}O_{2peak}$. COOLING included head and neck cooling with Elasto-Gel ice wraps (Southwest Technologies Inc., North Kansas City, MO) placed around the entire head and around the majority of the neck along with torso cooling using a modified Ironman® reflective vest with cooling packs (World Endurance Sports LLC, Tampa, FL). Cooling was administered for the entire 20 min. After 10 min, the ice packs were replaced with new packs from the freezer. At the end of the 20-min warm-up, all cooling packs were removed. The warm-up was identical during CONTROL trials except that there was no cooling.

Following the 20-min warm up, participants completed a simulated 16.1-km time trial as quickly as possible. During the time trial, HR was monitored continuously and recorded every km, along with measurement of rating of thermal comfort (RTC) and RPE. Furthermore, rectal temperature (T_{re}) and $\bar{T}_{sk}$ were monitored and recorded continuously at 50 Hz using a data acquisition system (Biopac MP150, Santa Barbara, CA). A fan circulating air at 3.3 m s^{-1} was directed at the front of participants during the time trial. Mean body temperature ($\bar{T}_b$) was calculated from T_{re} and $\bar{T}_{sk}$ according to the following equation[22]: Each trial was completed in a counterbalanced order to avoid any learning effect throughout the trials.

$$\bar{T}_b = (0.8 \times T_{re}) + \left(0.2 \times \bar{T}_{sk}\right)$$

Data are presented as means ± SD. Repeated Measures ANOVAs and paired samples t-test were used to test the significance of mean differences for primary outcome measures, time to completion of the simulated time trial, subjective ratings, and physiological measures (e.g., HR, T_{re}, $\bar{T}_{sk}$, RPE, RTC, and total time) between the COOLING and CONTROL trials. Furthermore, effect size was calculated for every variable using the Cohens D measurement method.[24] Data were analyzed using SPSS v. 20.0 (IBM, Inc., New York, NY), and *P*-values less than 0.05 were considered statistically significant (Fig. 1).

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