Continuous Forearm Cooling Attenuates Increase in Core Body Temperature of Elite Cyclists Under Heat Stress

Hedge ET,[1] Zuj KA,[1] Stothart AG,[1] Gavel EH,[2] Goodman LS,[3] Buckrell AJM,[4] and Peterson SD[1]

[1]University of Waterloo, Waterloo, ON, Canada
[2]University of Toronto, Toronto, ON, Canada
[3]Defence Research and Development Canada – Toronto Research Centre, Toronto, ON, Canada
[4]4iiii Innovations Inc., Cochrane, AB, Canada

ABSTRACT

Physical activity results in the generation of heat that is dissipated though thermoregulatory processes, such as the production of sweat. Environmental conditions can inhibit thermoregulation resulting in heat accumulation with eventual impairment in performance. **PURPOSE:** To determine if continuous inner forearm cooling helps to maintain body core temperature and athletic performance during cycling in a hot and humid environment. **METHODS:** Data were collected from 11 competitive triathletes [seven male, four female; age: 39 ± 13 years; mean ± standard deviation]. Each performed two cycling sessions at 68 ± 2% of their functional threshold power for up to 45 minutes in an environmentally controlled chamber (temperature: 30°C, humidity: 70%). One trial included continuous inner forearm cooling (FC), while the other was a control trial (NFC). Heart rate (HR) was monitored throughout the test and body core temperature (T_{core}) was measured using an ingestible radio capsule. Ratings of perceived exertion and thermal comfort were assessed every 10 minutes throughout exercise. **RESULTS:** Data suggest that forearm cooling attenuated the increase in T_{core} during exercise (FC: 1.99 ± 0.59 vs. NFC: 2.46 ± 0.71°C·hr^{-1}), as 81.7 ± 17.8 KJ of heat were removed from the body during the cooling trials. Furthermore, 5 of the 11 participants were unable to complete the non-cooling trial due to reaching the temperature threshold for test termination (39.3°C). Similarly, HR appeared to be lower in the FC condition compared to the NFC condition. Participants' ratings of perceived exertion and thermal comfort were slightly improved with inner forearm cooling. **CONCLUSION:** Data analysis suggests that during cycling in the heat, continuous cooling of the forearms may improve athlete comfort by attenuating the exercise induced increase in core body temperature.

INTRODUCTION

- In hot and humid environments, mechanisms of heat dissipation are impaired, as both convective and evaporative cooling mechanisms are compromised.
- Beneficial effects of pre-cooling normally attenuate after 20-25 min of exercise[1].
- Questions remain whether continuous cooling during exercise may be a more advantageous intervention to use during long duration endurance sports.

HYPOTHESIS

Continuous forearm cooling during exercise will reduce the rate of increase in core body temperature, and attenuate cardiovascular drift.

PARTICIPANTS

- 11 highly trained endurance athletes (7 males, 4 females, age: 39 ± 13 years, height: 1.73 ± 0.08 m, mass: 67 ± 10 kg, functional threshold power (FTP): 240 ± 49 Watts).

1. Bolster DR, et al. Effects of precooling on thermoregulation during subsequent exercise. *Med Sci Sports Exerc*. 1999; 31:251-7.

METHODS

- Two bouts of cycling separated by one week: 45min at 68 ± 2 % of self-reported FTP, with and without cooling
- Environmental chamber testing conditions:
  - Temperature 29.97 ± 0.21°C
  - Humidity 72.03 ± 1.71%
- Pre-/post-exercise body mass

Figure 1. Aluminum cooling plates (16cm x 4cm). Water at 5°C was continuously circulated through the plates. Heat extraction calculated from temperature change in the water.

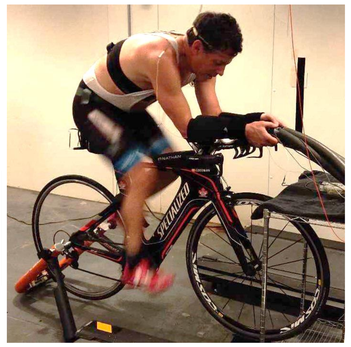

Figure 2. Experimental setup.

Table 1. Summary of equipment and measurements.

Equipment	Measurement
Equivital LifeMonitor	Heart rate
Garmin heart rate monitor	Heart rate
Thermistors	Water temperature
VitalSense temperature capsule	Core body temperature
STAC Zero Smart Trainer	Work rate and cadence

RESULTS

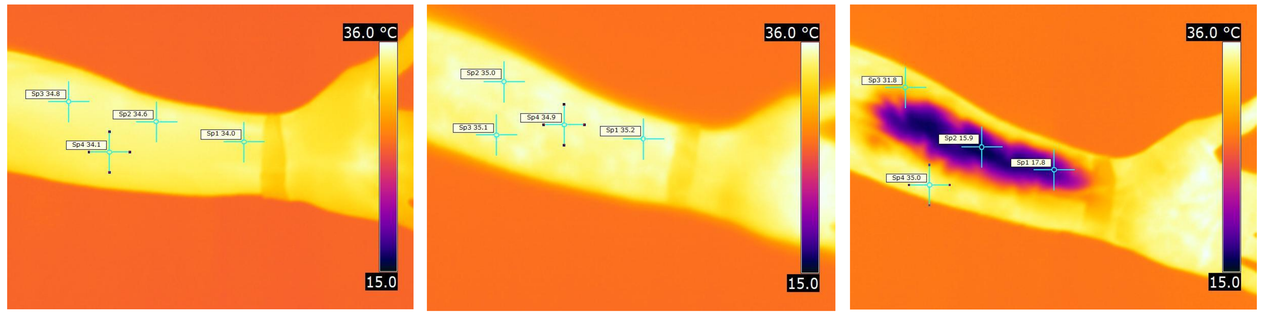

Figure 3. Thermal images of a representative participant's left forearm before cycling (left), after cycling for 45 min without (middle), and with (right) inner forearm cooling. Numbers on the arms in the images represent the skin temperature in degrees Celsius at each crosshair.

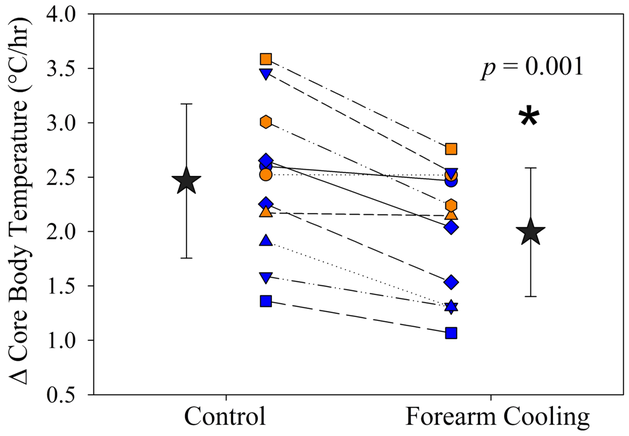

Figure 4. Comparison between conditions for the rate of increase in temperature during the 45min of cycling exercise. Blue symbols = males, and orange symbols = females.

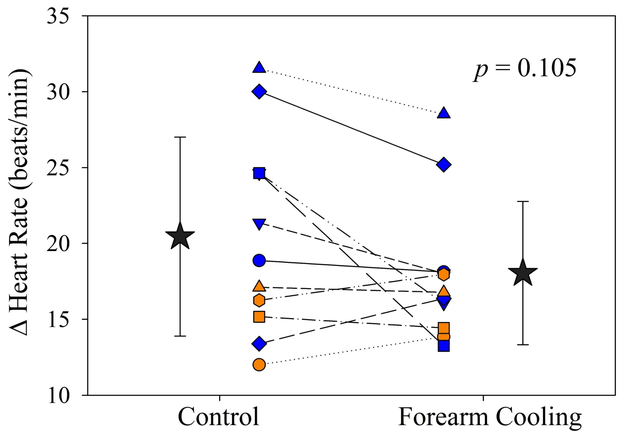

Figure 5. Comparison between conditions for cardiovascular drift. Cooling reduced cardiovascular drift for male (NFC: 23 ± 6, FC: 19 ± 6 beats/min; p = 0.021), but not female participants. Blue symbols = males, and orange symbols = females.

RESULTS

Table 2. Comparison between conditions for ratings of perceived exertion (RPE) and thermal comfort (TC) at the end of exercise.

	Control	Cooling	*p*-value
RPE	15 ± 2	14 ± 2	0.055
TC	10 ± 1	9 ± 1	0.002

RPE: 14 = somewhat hard, 15 = hard; TC: 9 = uncomfortably warm, 10 = hot.

- Body mass loss during exercise was not different between conditions (NFC: -1.60 ± 0.53, FC: -1.52 ± 0.50 kg/hr; p = 0.08).
- Cooling system extracted heat from the body at a rate of 30.3 ± 6.6 Watts, leading to 81.7 ± 17.8 KJ of heat being removed from the body over the duration of the 45 min of exercise.

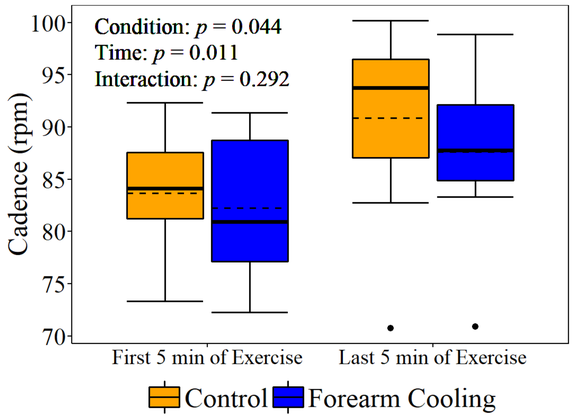

Figure 6. Comparison between conditions for cycling cadence. Within the boxes, solid line = median, and dashed line = mean.

CONCLUSION

- Continuous inner forearm cooling attenuated the exercise induced increase in core body temperature while cycling in a hot and humid environment.
- Potential sex-specific effects of cooling on cardiovascular drift.
- Cooling did not alter participants' pre-/post-exercise changes in body mass, but it did slightly improve their ratings of perceived exertion, and thermal comfort at the end of exercise.
- Potential applications for populations exposed to heat strain (military, first responders, athletics).
- Study shows proof of concept of the benefits of localized forearm cooling and provides support for future research and development into systems to utilize this effect.

ACKNOWLEDGMENTS

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