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Identification of the threshold ambient temperature above which pre-cooling has a performance benefit for time trials in the heat

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Introduction:
Endurance exercise performance progressively deteriorates as the surrounding ambient temperature increases,[1] which is exacerbated when combined with increasing humidity[2] and solar radiation.[3] It is clear that there is a strong link between increases in thermoregulatory strain, due to elevations in both metabolic and ambient heat, and impaired endurance performance.[4]
It has become commonplace to implement pre-cooling prior to competition to alleviate this performance decline, with ~50% of athletes having a defined strategy prior to competing in the heat.[5] Such strategies include the use of ice-vests, which have been suggested to improve time trial performance in the heat by approximately 5%.[6] However, little is known about the ambient temperature threshold above which pre-cooling becomes an effective strategy for enhancing endurance performance. With most studies focusing on a single ambient temperature, typically above 30˚C or a Wet Globe Bulb Temperature (WGBT) of 26˚C.[7] Therefore, it was the aim of this study to investigate the effect of pre-cooling in different environmental temperatures on time trial performance.
It was hypothesized that pre-cooling would improve time trial performance in all environmental temperatures, with the magnitude of effect dependent on environmental temperature.

Methods:
In an independent groups design, 24 trained male cyclists (age 24.3 ± 5.1 years; VO_{2max} 61.3 ± 3.7 mL·kg·min^{-}; training frequency ≥3 times per week) completed two time trials with (COLD) and without (CON) of pre-cooling using an ice-vest and sleeves ensemble. Pre-cooling was implemented for 30 minutes at rest and during a 9 minute progressive warm up, in ambient temperatures of 24.0 ± 0.1°C & 49.5 ± 1.4% *rh* (WBGT 19.2°C); 27.2 ± 0.3°C & 50.7 ± 5.3% *rh* (WBGT 22.1°C); or 35.0 ± 0.4°C & 50.6% ± 1.3% *rh* (29.2°C). Participants removed the cooling vest (if warn) on completion of the warm up, prior to completing a self-paced time trial designed to last ~60 minutes when ridden at ~75% W_{max}.

Results:
Time trial performance was 6.2% and 2.6% faster following COLD in both 35˚C and 27˚C (figure 1A) but not 24˚C (1.2%). Magnitude based inferential statistics indicate that COLD was *very likely beneficial* to performance in 35˚C and *likely beneficial* in 27˚C and *possibly beneficial* in 24°C. Mean power was 2.4% 2.5% and 5.6% higher following COLD (figure 1 B, C) and considered t o be *likely beneficial* in 24°C and *very likely beneficial* in 27˚C and 35˚C. There was no effect of COLD on gastrointestinal temperature at any point.

Conclusions:
Pre-cooling with an ice-vest and sleeves is likely to have a positive effect on time trial performance at temperatures above 24˚C, with a clear relationship between ambient temperature and the magnitude of effect of pre-cooling. These results indicate that cyclists should start to consider implementing a pre-cooling procedure prior to racing a time-trial in environmental temperatures of 24˚C and above. Importantly, utilising pre-cooling in lower ambient temperatures is unlikely to have a detrimental effect on performance at the cooling intensities used here. To the authors' knowledge, this is the first time that a lower ambient temperature threshold has been identified above which pre-cooling has a significant ergogenic impact on performance.

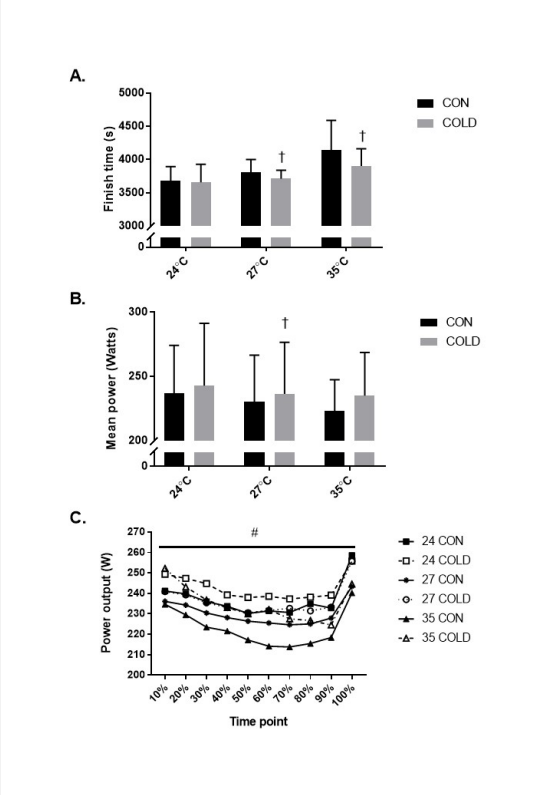

Figure 1: Performance data showing A) time trial completion times; B) mean power output and C) pacing profile. † denotes a significant difference from CON (P<0.05). # denote a significant effect of time (P<0.05). Data presented as mean ± SD.

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