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Acute physiological and perceptual responses to wearing additional clothing while cycling outdoors in a temperate environment: A practical method to increase the heat load

Abstract

This investigation assessed the acute physiological and perceptual responses to wearing additional clothing during outdoor cycling to determine if this strategy could increase the heat load while training in temperate environments. Seven male cyclists (age: 32±13 y, height: 179±10 cm, body mass: 74±10 kg, body fat percentage: 10.3±1.0%) completed two randomised outdoor (~17°C and ~82% RH), 80 min cycling sessions at moderate-hard intensities (CR10 RPE=3-5). They wore spandex shorts and a short sleeve top (CON) or additional clothing including full-length spandex pants and a 'winter' cycling jacket and gloves (AC). Core temperature, heart rate, sweat rate, thermal sensation and thermal comfort were measured across the trials. Moderate increases were observed in AC vs. CON for the change in mean core temperature (0.4±0.3°C, effect size, ES=1.16±0.55), change in maximum core temperature (0.5±0.3°C, ES=1.07±0.48) and sweat rate (0.24±0.16 $L \cdot h^{-1}$, ES=1.04 ± 0.59). A small increase in mean heart rate (3±3 bpm, ES=0.32±0.28) was observed as well as a '*very likely*' (percentage difference=22.4±7.1) and '*most likely*' (percentage difference=42.9±11.9) increase in thermal sensation and thermal comfort, respectively, in AC vs. CON. Dressing in additional clothing while cycling outdoors in a temperate environment increased physiological strain and sensations of warmth and discomfort. Training in additional clothing during outdoor cycling represents a practical alternative to increasing the heat load of a training session.

Keywords

Heat stress, heat training, restrictive heat loss attire, sweat clothing.

Abbreviations

AC = additional clothing trial

CL = confidence limits

CLO = thermal insulation of clothing

CON = control trial

ES = effect size

Hz = hertz

IAAF = International Association of Athletics Federations

RPE = rating of perceived exertion

Introduction

Training in a hot (>30°C) environment is a principle counter-measure to minimise heat-induced physiological strain, performance deterioration and heat illnesses in endurance athletes.[1] A meta-analysis of 52 data sets demonstrated a moderately beneficial effect of heat training on exercise performance and capacity in a hot environment[2] and consensus recommendations are to exercise in the heat for at least 60 minutes daily, across 1-2 weeks, to stimulate increased body temperatures and sweating.[1] As an example, 90 mins of low intensity cycling in the heat per day for five days significantly improved 20 km cycling performance time by 6%.[3] Despite the ergogenic effects of training in the heat and simple guidelines, it has been reported that only 13% of long distance athletes at the 2015 Beijing IAAF World Athletics Championships (where hot conditions were expected) followed a heat-training regime.[4] Indeed, heat training may not be practical for athletes, especially for those with limited access to a hot natural or artificial environment. Such training may require specialised equipment, expensive travel, as well as altering the normal training environment and/or pre-competition taper, making it disruptive and threatening to an athlete's routine and performance outcome, respectively.[5]

An alternative practical technique to increase heat load during training, in an individual residing in a temperate environment (15-25°C), could involve the use of restrictive heat loss attire (e.g. 'sweat clothing' or a vinyl 'sauna suit'). Wearing sweat clothing in a temperate laboratory (20-22°C) can significantly increase thermoregulatory and physiological strain during endurance exercise.[6,7] However the laboratory-based nature of these studies[6,7] limits application for athletes

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training outdoors, especially cyclists who experience a very high convection load and marked cooling during training.[8] Practicality, it makes sense for an athlete to use simple clothing that they already own, such as winter training garments, to increase heat load when within a temperate environment. However the efficacy of such a strategy, has not, to our knowledge, been examined. Given uncertainty surrounding the use of training in additional clothing as a potential method to increase the heat load, the current study aimed to assess the acute physiological and perceptual responses to wearing additional clothing during outdoor cycling in a temperate environment. It was hypothesized that wearing the additional clothing would increase the heat load and the sweating response compared to control.

Methods

Participants

Seven male trained cyclists/triathletes (mean±SD; age: 32±13 y, height: 179±10 cm, body mass: 74±10 kg, body fat percentage: 10.3±1.0%) volunteered for the study. Participants were currently completing a minimum of six hours of cycling training per week, with the majority also completing another three-four hours of swimming and running. Participants were not seasonally acclimated and had not undergone a heat acclimation program within the last 6 months. The Human Research Ethics Committee at Southern Cross University granted approval for the project (ECN-16-198). Participants provided written informed consent prior to engaging in all study procedures.

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Study Design

In a randomised cross-over design, participants completed two outdoor cycling trials on separate days, 4-7 days apart, during the Australian early Spring season (September-October; ~17±2°C and ~82±6% RH; range=12.7-18.5°C and 74-88%). Participants completed one trial in spandex shorts and a short sleeve top (CON) and the other in additional clothing (AC) consisting of full-length spandex pants and a 'winter' cycling jacket (Sub Zero Cycling Jacket, 2XU, Melbourne, VIC, Australia) and gloves made of a combination of nylon, polyurethane and polyester (dry mass of additional clothing=0.9-1.1 kg).

Experimental Trial

For 24 h prior to each trial, caffeine, alcohol and high intensity exercise were not permitted. An anthropometric profile including mass, stature and skinfolds at seven sites were obtained from each participant.

Each session consisted of 80 min of cycling in total including 20 min at a CR-10 rating of perceived exertion[9] of 3 ("moderate"), 40 min at 5 ("hard") and another 20 min at 3 ("moderate"). Each subject rode the same route for both trials but there were small differences in selective routes between participants (mean elevation change=170±24 m, mean distance=35.2±2.5 km). Water with a starting temperature of 33°C was allowed *ad libitum* throughout the sessions from a thermal drink bottle.

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Measures

Towel dried nude mass was measured before and after each trial, which was corrected for fluid ingestion to estimate sweat rate ($L \cdot h^{-1}$) as follows:

$$\textit{Sweat rate} = (\Delta \textit{mass} + \textit{ingested fluid}) / \textit{exercise time}$$

Core temperature was measured across the 80 minute cycling session continuously every 30 s using an indigestible telemetric capsule (e-Celsius Performance, BodyCAP, Caen, France) consumed 8 hours prior to arrival and calibrated as recommended.[10] Heart rate and cycling distance were continuously measured at 1 Hz by a Garmin Forerunner 920XT monitor (Garmin Ltd., Schaffhausen, Switzerland). Mean thermal sensation was measured using Young's 17-point category ratio scale, where 0=unbearably cold and 8=unbearably hot, and mean thermal comfort was measured using a modified 10-point category ratio scale where 1=comfortable and 10=extremely uncomfortable. Ambient temperature and relative humidity were recorded upon starting and finishing each trial, using data obtained from the local weather station.

Statistical Analysis

Measurements are presented as mean±standard deviation (SD) and were analysed using a magnitude-based inference approach.[11] For physiological responses, the magnitude of the changes between trials was expressed as standardised differences (Cohen's D effect sizes; ES). The criteria used for interpreting the magnitude of the ES were: ≤0.2 (trivial), >0.2 (small), >0.6 (moderate), >1.2 (large) and >2.0 (very large).[11] ES differences, with uncertainty of the estimates shown as 90% confidence limits (CL), were determined using published spreadsheets (xPostOnlyCrossover.xls) available at sportsci.org.[11] Trivial thresholds were set at 0.20. If the 90% confidence intervals overlapped positive or negative trivial ES values, the effect was deemed unclear. For change in physiological responses, the smallest worthwhile change was calculated as 0.2 multiplied by the between subject SD. For change in perceptual responses, an approach called full-scale deflection was adopted. Magnitude-based thresholds were used to determine the smallest worthwhile change (10%) in each perceptual variable.[12] A range was made from 0-100% and magnitude thresholds were defined as 10%, 30%, 50%, 70% and 90% for small, moderate, large, very large and extremely large changes, respectively.[12] Quantitative chances of measurements affecting performance were assessed qualitatively as follows: <1%, most unlikely; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possible; 75-95%, likely; 95-99%, very likely; >99% most likely.[11] When an effect was >5% for both substantial increases and decreases, the true value of the difference was deemed unclear.

Results

Temperature data are reported as a change from baseline (delta) as high variance in baseline temperatures were observed. On average, participants began the AC trial 0.3°C cooler and completed the AC trial 0.1°C hotter compared to CON. The time course of delta core temperature between conditions appears in Figure 1. After 2 min, all values in AC were greater than the smallest worthwhile change compared to CON. Group mean physiological and perceptual responses across the trials are shown in Table 1 and Table 2, respectively.

Moderate increases were observed in AC compared to CON for the change in mean core temperature (0.4±0.3°C, effect size, ES=1.16±0.55), maximum core temperature (0.5±0.3°C, ES=1.07±0.48) and sweat rate (0.24±0.16 $L·h^{-1}$, ES=1.04 ± 0.59). A small increase in mean heart rate (3±3 bpm, ES=0.32±0.28) was observed in AC compared to the CON. All other calculated ES statistics were deemed unclear. Individual core temperature, sweat rate and heart rate responses are presented in Figure 2. All individual differences between conditions were above the smallest worthwhile change except for the heart rate of one rider.

For perceptual responses, there were '*very likely'* (percentage difference±90% CL: 22.4±7.1) and '*most likely'* (42.9±11.9) increases in thermal sensation and thermal comfort, respectively, in AC compared to CON.

Discussion

The data demonstrates a practical method of wearing additional clothing, during cycling outdoors in a temperate environment, can acutely increase thermo-physiological strain, as measured by an elevated core temperature, sweat rate and heart rate (Table 1). Increased core temperatures and sweat rates were observed in every subject, with only one subject presenting with a lower heart rate. Additional clothing also produced a large perceptual response, especially for thermal comfort (Table 2).

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The simple strategy of wearing additional clothing increased the heat load on the athletes without specialised equipment, expensive travel, or altering the normal training environment. This strategy may be useful within a heat acclimation program, or for ergogenic outcomes in cool conditions.[13] In practice, this strategy could be adjusted to suit individual needs, for example, by increasing the quantity and/or thermal properties of the clothing to increase or decrease the heat load as necessary. Also, prolonging the 'hard' intensity period (20-60 min of the trial) would likely increase the maximum core temperature achieved, considering the linear increase in delta core temperature up to the 60 min time-point (Figure 1). It should be made clear that the training session used in the current study is not the ideal heat training session for all athletes. Instead of using this session specifically, it is recommended that athletes follow their normal training routine, and apply additional clothing when a heat stimulus is required. However, increases in physiological strain and psychological stress whilst wearing additional clothing may reduce the quality of self-paced training prescribed at a high intensity.[14] Therefore, close monitoring of training load and wellness (with the strategies that the athlete and coach usually use on a daily basis) is recommended when training in additional clothing to ensure that the added heat load does not negatively influence training outcomes.

It should be noted that the gastrointestinal temperature measurement site and outdoor-based protocol used (where a high convection load was present), likely reduced the core temperature response compared with what is typically observed in laboratory studies. Previous laboratory studies have demonstrated that exercise in restrictive heat loss attire may replicate thermoregulatory responses to exercise in a hot laboratory environment at 34-40°C[6] but not at

45°C.[7] While the physiological responses to outdoor training in the heat were not measured (limiting the recommendations of the current study), the use of additional clothing achieved recommendations for training in the heat as described previously.[1] Hence, future research should investigate the capacity for such a strategy to induce heat acclimation adaptations by using the intervention on a daily basis across a 2-week training program.[1] The assessment of endurance performance in a time-trial protocol with adequate facing wind speed to simulate the convective cooling of cycling outdoors should also be implemented.[15,16] Mechanistic evidence to support heat acclimation has occurred is also recommended, principally plasma volume expansion and quantification of intra- and extra-cellular heat shock proteins.

Conclusions

Over-dressing in 'winter' training garments during outdoor cycling in a temperate environment is an effective strategy to increase the heat load of a training session via augmented thermo-physiological and psychological strain. Therefore, this strategy may have the potential to serve as an alternative method to increase the heat load for acclimation and/or ergogenic outcomes. Future research should investigate the efficacy of repeated training in additional clothing to establish the chronic performance, physiological and molecular responses.

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Disclosure Statement

No potential conflicts of interest were reported by the authors.

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Figure captions

Figure 1. Time course of delta core temperature across the training session with additional clothing (AC) and without (CON). *Indicates an increase greater than the smallest worthwhile change in AC compared to CON.

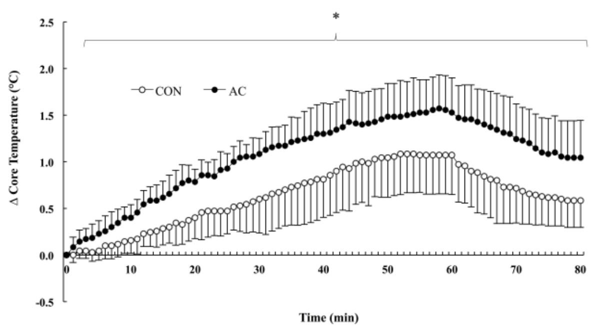

Figure 2. Individual delta mean core temperature (A), delta maximal core temperature (B), heart rate (C), and sweat rate (D) responses with additional clothing (AC) and without (CON). *Indicates an increase greater than the smallest worthwhile change in AC compared to CON.

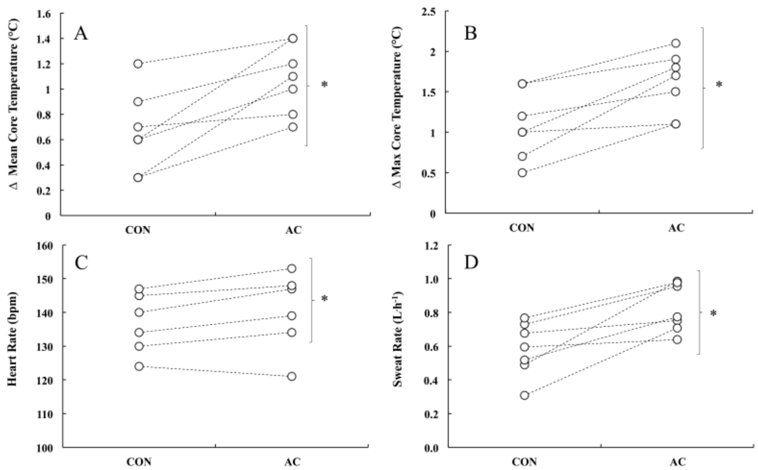

Table 1. Group responses, standardised differences and qualitative chances of increase with additional clothing (AC) compared to control (CON).

Variable	CON Mean±SD (range)	AC Mean±SD (range)	Effect Size	90% CL	Qualitative ES	% Chances	Qualitative Chance of Increase
Δ Mean T_C (°C)*	0.7±0.3 (0.3-1.2)	1.1±0.3 (0.7-1.4)	1.16	0.55	Moderate	99/1/0	*Very likely*
Δ Max T_C (°C)*	1.1±0.3 (0.5-1.6)	1.6±0.4 (1.1-2.1)	1.07	0.48	Moderate	99/1/0	*Very likely*
Mean T_C (°C)*	37.6±0.2 (37.3-37.8)	37.7±0.4 (37.1-38.2)	0.38	1.38	Unclear	60/29/21	*Unclear*
Sweat rate ($L \cdot h^{-1}$)	0.58±1.6 (0.31-0.77)	0.83±1.4 (0.64-0.98)	1.04	0.59	Moderate	98/2/0	*Very likely*
Heart rate (bpm)	137±9 (124-147)	140±12 (121-153)	0.32	0.28	Small	80/20/1	*Likely*
Fluid intake (L)	0.2±0.18 (0.1-0.57)	0.21±0.23 (0-0.67)	0.06	0.71	Unclear	36/40/24	*Unclear*
Temperature (°C)	17.3±0.7 (16.5-18.5)	16.3±2.5 (12.7-18.5)	-1.66	2.40	Unclear	9/6/86	*Unclear*
Humidity (%)	81±6 (74-88)	83±6 (74-88)	-0.19	1.20	Unclear	28/23/29	*Unclear*

Δ = delta, bpm=beats per minute, CL = confidence limits, ES = effect size, SD=standard deviation, T_C = core temperature.
*Measures observed across the entire 80-minute cycling period.

Table 2. Group perceptual responses, change in the mean and qualitative chances of increase with additional clothing (AC) compared to control (CON).

Variable	CON Mean±SD (range)	AC Mean±SD (range)	Change in mean (%)	90% CL	% Chances	Qua
Thermal sensation (AU)	4.1±0.4 (3.5-4.5)	5.7±0.6 (5-6.5)	22.4	7.1	99/1/0	
Thermal comfort (AU)	1±0 (1-1)	4.9±1.5 (3-6)	42.9	11.9	100/0/0	

AU = arbitrary units, CL = confidence limits, SD = standard deviation.