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The influence of upper-body pre-cooling on repeated sprint performance in moderate ambient temperatures

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In this study, we examined the effects of upper-body pre-cooling before intermittent sprinting exercise in a moderate environment. Seven male and three female trained cyclists (age 26.8 ± 5.5 years, body mass 68.5 ± 9.5 kg, height 1.76 ± 0.13 m, $\dot{V}O_{2peak}$ 59.0 ± 11.4 $mL \cdot kg^{-1} \cdot min^{-1}$; mean ± *s*) performed 30 min of cycling at 50% $\dot{V}O_{2peak}$ interspersed with a 10-s Wingate cycling sprint test at 5 min intervals. The exercise was performed in a room controlled at 22°C and 40% relative humidity. In the control session, the participants rested for 30 min before exercise. In the pre-cooling session, the participants wore the upper segment of a liquid conditioning garment circulating 5°C coolant until rectal temperature decreased by 0.5°C. Rectal temperature at the start of exercise was significantly lower in the pre-cooling (36.5 ± 0.3°C) than in the control condition (37.0 ± 0.5°C), but this difference was reduced to a non-significant 0.4°C throughout exercise. Mean skin temperature was significantly lower in the pre-cooling (30.7 ± 2.3°C) than in the control condition (32.5 ± 1.6°C) throughout exercise. Heart rate during submaximal exercise was similar between the two conditions, although peak heart rate after the Wingate sprints was significantly lower in the pre-cooling condition. With pre-cooling, mean peak power (909 ± 161 W) and mean overall power output (797 ± 154 W) were similar to those in the control condition (peak 921 ± 163 W, mean 806 ± 156 W), with no differences in the subjective ratings of perceived exertion. These results suggest that upper-body pre-cooling does not provide any benefit to intermittent sprinting exercise in a moderate environment.

Keywords: anaerobic exercise, fatigue, hyperthermia, liquid conditioning garments, regional pre-cooling.

Introduction

Hyperthermia, brought about by a body heat load in excess of its heat dissipation capacity, is well-established as a limiting factor in exercise performance (MacDougall *et al.*, 1974; Nielsen, 1992; Gonzalez-Alonso *et al.*, 1999). The increased body heat load may be endogenous due to increased metabolic production during prolonged submaximal or high-intensity exercise. Alternatively, the ambient environment may be a significant source of exogenous heat, with submaximal exercise performance significantly impaired even at a relatively moderate temperature of 21°C compared with 11°C (Galloway and Maughan, 1997).

When cooling garments cannot be worn during exercise, an alternative counter-measure is to pre-cool individuals before the initiation of exercise, thereby permitting a greater body heat storage capacity (Marino, 2002). The efficacy of pre-cooling before prolonged submaximal exercise has been demonstrated with a variety of pre-cooling modalities, such as showers and cool water immersion (Lee and Haymes, 1995; Booth *et al.*, 1997). Many athletic and occupational activities, such as the points race in track cycling or criteriums in road cycling, require high-intensity efforts interspersed with periods of moderate exercise, a type of effort also impaired by high ambient temperatures (Kay *et al.*, 2001; Yasumatsu *et al.*, 2001). Therefore, pre-cooling should also reduce the impact of fatigue not only during endurance activities, but also during repeated high-intensity sprint exercise.

The efficacy of pre-cooling before sprinting exercise is equivocal. Marsh and Sleivert (1999) reported increased power output during a 70 s power test following 30 min cold water immersion, possibly through skin vasoconstriction increasing blood flow to the active musculature during the subsequent 10 min warm-up. In contrast, whole-body pre-cooling did not benefit power output during either an intermittent

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soccer simulation treadmill run (Drust *et al.*, 2000) or a 45 s Wingate sprint (Sleivert *et al.*, 2001). Nevertheless, torso and thigh pre-cooling decreased both peak and mean power during a single Wingate sprint, whereas power outputs were similar with either torso-only pre-cooling or with no pre-cooling (Sleivert *et al.*, 2001). Therefore, direct cooling of the active musculature may have countered any benefit from decreases in overall body heat content, such that it may be preferable to pre-cool only the torso and avoid cooling of the legs before intermittent lower-body sprinting exercise.

In a study of the efficacy of torso-only cooling, Duffield *et al.* (2003) reported no benefits of wearing an ice jacket before and during 80 min of intermittent cycling sprinting exercise in a hot environment. However, the jacket was worn for only 5 min before exercise, which did not allow any significant pre-cooling of core temperature. Therefore, the aim of the present study was to examine the effects of upper-body pre-cooling on thermoregulatory responses and power outputs during repeated sprint performance by achieving a decrease in overall core temperature while avoiding cooling of the active leg musculature. Pre-cooling was performed using a liquid conditioning garment that covered only the head and upper body (torso and arms). We hypothesized that upper-body pre-cooling would increase repeated power outputs during intermittent sprints by reducing the thermoregulatory strain associated with exercise.

Methods

Participants

Seven males and three females (age 26.8 ± 5.5 years, body mass 68.5 ± 9.5 kg, height 1.76 ± 0.13 m, body fat 11.7 ± 5.6%, $\dot{V}O_{2peak}$ 59.0 ± 11.4 $mL \cdot kg^{-1} \cdot min^{-1}$) participated in each of two experimental trials after receiving medical clearance and providing their written informed consent. The participants were all competitive cyclists recruited from local cycling and triathlon clubs. The protocol was approved by the Dalhousie University Health Sciences Research Ethics Board. The participants were requested to consume the same diet and to refrain from intense physical activity, caffeine or alcohol in the 24 h before each session. To ensure euhydration, body mass was measured on arrival at the laboratory and compared with baseline values (tolerance of ± 1%).

Protocol

On an initial test day, anthropometric variables were measured and peak aerobic capacity ($\dot{V}O_{2peak}$) was determined using open-circuit spirometry. The participants cycled on their own bicycles attached to a CompuTrainer resistance trainer (CompuTrainer, Redmond, WA) at 60 W for 4 min, after which the work rate was increased by 30 W every minute until exhaustion. The participants were given verbal encouragement throughout the test. Expired air was collected and analysed in 30 s averages throughout the test to determine oxygen uptake (VO_{2000}, Aerosport, Ann Arbor, MI). Heart rate was monitored throughout the test using a telemetric heart rate monitor (Polar Vantage XL, Kempele, Finland). After a rest period, the participants then exercised at three submaximal work intensities (corresponding to ~40, 50 and 60% $\dot{V}O_{2peak}$) for 4 min, and a regression was performed to obtain the work load corresponding to 50% $\dot{V}O_{2peak}$. The participants also practised the Wingate sprint protocol in this session to familiarize them with the task.

Intermittent sprint performance was determined on two separate occasions (separated by at least 72 h). The participants cycled in a moderate (22°C dry bulb temperature, 40% relative humidity) laboratory environment while either being pre-cooled to a core temperature of 0.5°C (pre-cooling condition) or not being pre-cooled (control condition), with the amount of pre-cooling being consistent with that achieved in previous studies. The participants were tested at similar times of the day (generally the early afternoon), which were kept consistent within participants to minimize core temperature fluctuations due to the circadian rhythm.

For the pre-cooling trials, the participants rested in a sitting position while wearing a liquid conditioning garment (Med-Eng Inc., Pembroke, Canada) consisting of a full coverage hood (except the face) and a long-sleeved garment that covered the torso and arms (except the hands). The hood and torso of the liquid conditioning garment consisted of approximately 44 m of polyvinyl tubing stitched into a tight-fitting garment. Cooling was provided by a chiller, and the garment's inlet water temperature was 5.0°C. Cooling continued until rectal temperature decreased by 0.5°C or the garment was worn for 75 min, whichever was the earlier. The participants removed the liquid conditioning garment and were then seated on the cycle ergometer (Monark 824E, Monark, Sweden). In the control trials, the participants were fully instrumented and then remained in a sitting position for 30 min before the initiation of exercise. Transfer from the resting/cooling phase to the initiation of the sprinting protocol was generally accomplished in less than 5 min.

Following transfer to a Monark ergometer, the participants performed a 10 s Wingate cycling protocol with a resistive load of 0.09 $kp \cdot kg^{-1}$. The participants then performed continuous cycling on the Monark ergometer at 50% $\dot{V}O_{2peak}$ for 30 min. At 5, 10, 15, 20, 25 and 30 min, the participants performed another 10 s

Wingate sprint. After each 10 s sprint, the participants rested for 20 s, pedalled at 50% $\dot{V}O_{2peak}$ for 4 min, rested for 20 s, and then accelerated to maximal cadence against no resistance for 10 s.

Measured variables

Rectal temperature (T_{re}) was recorded with a copper-constantan thermocouple (Mon-A-Therm General, Mallinckrodt Medical, St. Louis, MO) inserted 15 cm beyond the anal sphincter. Skin temperature (T_{sk}) was measured with copper-constantan thermocouples (Mon-A-Therm Skin, Mallinckrodt Medical, St. Louis, MO) at the calf, thigh, chest and upper arm and calculated as an unweighted mean ($\overline{T}_{sk}$). The temperatures of the calf and thigh were chosen to represent the non-cooled regions, while those of the chest and upper arm represented the cooled regions. Both rectal temperature and skin temperature were recorded on a custom-built data acquisition system written with Labview 5.1 software (National Instruments, Austin, TX) every 30 s and averaged over each 5 min interval. Mean body temperature was calculated as $0.65\ T_{re} + 0.35\ \overline{T}_{sk}$ (Burton, 1935). Heart rate was measured with a telemetric sensor (Polar Vantage XL) and recorded halfway through each submaximal cycling bout; peak heart rates were calculated after each sprint. The participants wore an oronasal mask and expired gases were collected and analysed for oxygen uptake. The subjective perception of physical effort was measured during each submaximal cycling bout and after each Wingate sprint using a 16-point ratings of perceived exertion (Borg, 1982). Overall thermal sensation was rated during the thermal manipulation and midway through each submaximal cycling bout with a 21-point thermal comfort vote, ranging from +10 ('very very hot') to -10 ('very very cold'), with 0 as neutral (Mekjavic *et al.*, 1994). Blood lactate concentrations were obtained using a fingerprick blood sample (Accusport, Boehringer Mannheim, Mannheim, Germany) taken 3 min after the start of the fourth ($t = 18$ min) and seventh ($t = 33$ min) Wingate sprint.

Power during the Wingate sprints was recorded at 1 s intervals using custom-designed software (Power v1.0, Sports Medicine Industries Inc., St. Cloud, MN). Peak power output was the mean of the first 5 s, while mean power output was the mean for the entire 10 s sprint.

Statistical analysis

Rectal temperature, mean skin temperature, mean body temperature, heart rate, blood lactate concentration, oxygen uptake ($\dot{V}O_2$), peak power output and mean power output were compared using a two-factor (condition × time) repeated-measures analysis of variance (ANOVA). A Bonferroni *post-hoc* test was performed to locate any pairwise differences. Thermal comfort votes and ratings of perceived exertion were analysed non-parametrically using a Friedman two-way ANOVA. Statistical significance was set at $P < 0.05$.

Results

Temperature responses

During the 30 min resting phase in the control condition, rectal temperature decreased slightly but non-significantly so from $37.2 \pm 0.4°C$ to $37.0 \pm 0.5°C$ at the start of exercise. Pre-cooling significantly lowered rectal temperature compared with the control condition, decreasing from a baseline of $37.0 \pm 0.4°C$ to $36.6 \pm 0.3°C$ at the end of the cooling phase, with a further fall in rectal temperature to $36.5 \pm 0.3°C$ at the start of exercise ($F = 12.60$, $P = 0.004$). Mean skin temperature was also decreased by 2.9°C with pre-cooling ($F = 23.15$, $P < 0.000$), resulting in a lower mean body temperature ($F = 33.50$, $P < 0.001$) at the start of exercise in the pre-cooling condition ($33.8 \pm 0.6°C$) than in the control condition ($35.2 \pm 0.7°C$).

The changes in rectal temperature, mean skin temperature and mean body temperature during the exercise phase are presented in Fig. 1. Over the course of the 30 min exercise phase, rectal temperature increased steadily, with a rise of approximately 1.2–1.3°C in both the control and pre-cooling trials. Rectal temperature in the pre-cooling condition remained approximately 0.4°C lower than in the control condition throughout the course of exercise, though this was statistically non-significant ($F = 1.47$, $P = 0.18$). A main effect of condition was observed with both mean skin and mean body temperature, with mean skin temperature $\sim 1.4°C$ ($F = 22.1$, $P < 0.002$) and mean body temperature $\sim 0.8°C$ ($F = 21.11$, $P = 0.001$) lower throughout the course of exercise in the pre-cooling condition. Mean skin and mean body temperature were also significantly lower during pre-cooling at each time point during exercise.

Power output

Peak power output (average of the first 5 s) of the Wingate sprint, together with mean power output over the entire 10 s sprint, are presented in Fig. 2. In both the control and pre-cooling conditions, peak power output and mean power output during the first sprint (no warm-up) were significantly lower ($F = 6.89$, $P < 0.004$) than during all other sprints, while subsequent

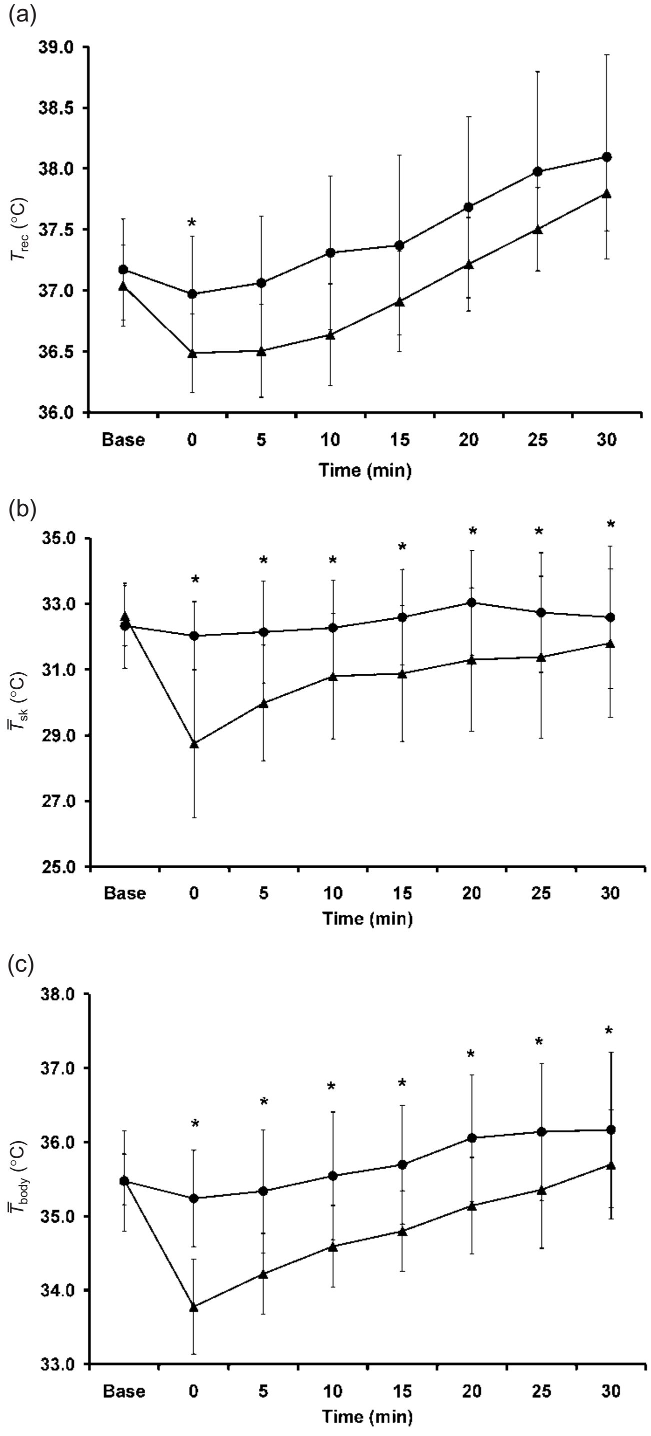

Fig. 1. Thermal responses following control (●) and pre-cooling (▲) to the 30 min cycling protocol (50% $\dot{V}\text{O}_{2\text{peak}}$ interspersed with 10 s Wingate sprints at 5 min intervals) of (a) rectal temperature (T_{rec}), (b) unweighted mean skin temperature ($\bar{T}_{\text{sk}}$) of the chest, upper arm, thigh and calf, and (c) mean body temperature ($\bar{T}_{\text{body}}$). * Rectal temperature was significantly lower ($P < 0.05$) at the start of exercise with pre-cooling, and mean skin temperature and mean body temperature were lower with pre-cooling throughout exercise.

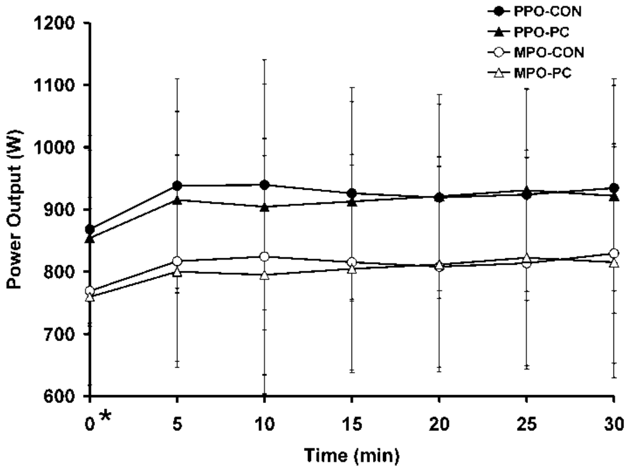

Fig. 2. Peak power outputs (PPO, solid symbols) and mean power outputs (MPO, open symbols) for 10 s Wingate sprints after the control (CON, circles) and pre-cooling (PC, triangles) conditions. * Peak and mean power outputs for the first sprint were significantly lower ($P < 0.05$) than all subsequent sprints in both the control and pre-cooling trials.

sprints demonstrated a plateauing of power output responses. No difference in power output ($F = 1.08$, $P = 0.325$) was observed between the two conditions during any sprint.

Cardiovascular and metabolic responses

The cardiovascular and metabolic responses to the submaximal cycling and the Wingate sprints are shown in Tables 1 and 2, respectively. Heart rate responses were analysed separately for the submaximal cycling bouts and following the Wingate sprints. A slight decrease in heart rate was evident during the first bout of submaximal cycling ($F = 39.84$, $P < 0.001$), but this disappeared in subsequent bouts. A main effect was observed across conditions following the Wingate sprints, with heart rates slightly but significantly lower in the pre-cooling condition ($F = 7.73$, $P = 0.021$).

The pre-cooling protocol was successful in reducing core temperature without causing significant shivering, as demonstrated by the similar oxygen uptakes of 3.9 ± 0.8 and 4.0 ± 1.2 mL·kg^{-1}·min^{-1} ($F = 3.26$, $P = 0.105$) during the resting and pre-cooling phases, respectively. Oxygen uptake increased gradually throughout exercise in both the control and pre-cooling trials, rising from 30.4 ± 7.4 and 28.6 ± 5.2 mL·kg^{-1}·min^{-1} respectively (~50% $\dot{V}\text{O}_{2\text{peak}}$) in the first bout to 35.6 ± 8.3 and 34.6 ± 7.4 mL·kg^{-1}·min^{-1} (~60% $\dot{V}\text{O}_{2\text{peak}}$) respectively in the final bout ($F = 18.46$, $P < 0.001$). No differences ($F = 1.31$, $P = 0.28$) were observed in oxygen uptake between the control and pre-cooling conditions.

Table 1. Baseline values during the 30 min rest (control) and pre-cooling conditions and 50% peak oxygen uptake (values recorded halfway through each bout) cycling responses of heart rate, oxygen uptake, subjective thermal comfort vote (TCV, − 10 = 'very very cold', + 10 = 'very very hot', 0 = neutral) and ratings of perceived exertion (RPE, 6–20 scale) (mean ± *s*)

Time interval (min)	Heart rate (beats · min^{-1})		TCV		RPE		$\dot{V}O_2$	
	Control	Pre-cooling	Control	Pre-cooling	Control	Pre-cooling	Control	Pre-cooling
Baseline	63±15	59±12	0±1	−6±2*			3.9±0.8	4.0±1.2
0–5	136±13	127±17	2±1	−2±2*	12±2	12±1	30.4±7.4	28.6±5.2
5–10	143±13	139±17	3±1	1±2*	12±2	12±1	33.7±8.0	32.3±6.1
10–15	147±12	142±15	4±2	3±2	12±2	12±2	33.8±7.7	33.7±6.5
15–20	149±15	148±14	5±1	4±2	13±2	13±2	34.2±6.8	33.6±7.1
20–25	152±14	150±16	5±2	5±1	13±2	13±2	34.5±7.0	34.8 ± 7.2)
25–30	153±16	153±16	5±2	5±1	14±2	13±2	35.6±8.3	34.6±7.4

* Significantly different ($P < 0.05$) from control.

Table 2. Wingate sprinting responses at 5 min intervals for peak heart rate and ratings of perceived exertion (6–20 scale) during the 30 min rest (control) and pre-cooling conditions (mean ± *s*)

Sprint # (*t* = min)	Heart rate (beats · min^{-1})		RPE		Blood lactate conc. (mmol · l^{-1})	
	Control	Pre-cooling*	Control	Pre-cooling	Control	Pre-cooling
1 (*t* = 0)	148±12	144±11	15±2	14±2		
2 (*t* = 5)	163±10	155±12	16±2	16±1		
3 (*t* = 10)	170±10	163±14	16±2	16±2		
4 (*t* = 15)	171±11	167±12	17±1	17±2	8.5±4.3	8.6±2.7
5 (*t* = 20)	172±13	170±13	17±1	17±1		
6 (*t* = 25)	173±12	171±15	18±1	17±1		
7 (*t* = 30)	175±14	171±15	18±1	17±1	7.1±3.1	7.9±3.4

Note: Blood lactate concentration was measured 3 min post-sprint at *t* = 18 and 33 min. *Significantly different ($P < 0.05$) from control.

The blood lactate response remained stable throughout the exercise session, with no difference in blood lactate concentrations either between conditions ($F = 1.45$, $P = 0.26$) or between the fourth and seventh sprint ($F = 0.39$, $P = 0.55$).

Subjective responses to exercise

Pre-cooling with the liquid conditioning garment and 5°C coolant resulted in a colder subjective rating of thermal comfort ($F = 18.03$, $P < 0.001$) both before exercise and for the initial 10 min of the exercise session (Table 1). Though no sweat collection occurred, observation of the participants showed that visible sweating began about 10 and 20 min into exercise during the control and pre-cooling condition, respectively. This cooler thermal sensation did not have any effect on the subjective ratings of perceived exertion during either submaximal cycling ($F = 0.75$, $P = 0.41$) or the Wingate sprints ($F = 2.15$, $P = 0.18$) (Tables 1 and 2).

Discussion

Pre-cooling has become increasingly common as an ergogenic aid before some athletic competitions, most notably the use of ice vests by rowers to minimize heat storage during warm-ups (Marino, 2002). However, its efficacy before sprinting or intermittent sprinting exercise remains unclear. The pre-cooling protocol used in the current experiment was designed to address some of the potential limitations observed in previous studies on the effects of pre-cooling on sprinting performance (Marino, 2002). Pre-cooling by either whole-body water immersion or air exposure may bring about overly rapid reductions in core or skin temperature, leading to the possibility of significant shivering and muscular fatigue before exercise (Booth *et al.*, 1997). Additionally, exposure of the legs to pre-cooling has been reported to impair subsequent sprinting performance (Sleivert *et al.*, 2001). We therefore opted to pre-cool trained cyclists using a liquid conditioning garment that decreased core temperature by similar amounts (~0.5°C) as other protocols (Booth *et al.*, 1997; Marsh and Sleivert, 1999; Sleivert *et al.*, 2001), but maintained skin temperature of the lower body at a normothermic value of ~32°C. However, as with the few existing studies on whole-body pre-cooling effects on high-intensity exercise (Drust *et al.*, 2000), the present protocol did not demonstrate any differences in either peak or mean power output during intermittent 10 s Wingate sprints.

Previous research examining localized pre-cooling of the upper body has also not reported improved sprinting performance with either single sprints (Sleivert *et al.*, 2001) or repeated sprints (Duffield *et al.*, 2003) in the heat. Combined with the present observations, it is possible that the pre-cooling strategy of targeting the upper body may have precluded any ergogenic effect through thermal manipulation of the active leg musculature before the initial sprint. Most of the decrease in mean skin temperature was due to a lower skin temperature of the chest and arms, and the skin temperature of the thigh and calf remained similar between the control and pre-cooling treatments during both the resting/pre-cooling phase and the exercise phase (data not shown). Although no muscle temperatures were measured, this would suggest no significant cooling of the lower body musculature. Furthermore, as submaximal workload was clamped and no differences were observed in maximal oxygen uptake, blood lactate concentration or the rate of increase in rectal temperature, it is likely that no differences in muscle thermal status occurred between the control and pre-cooling conditions during the 30 min exercise protocol, which may have contributed to the overall similarity in power output responses throughout exercise. The lower peak and mean power outputs in the initial sprint might have reflected the lack of a warm-up before the sprint (Sleivert *et al.*, 2001), though it is possible that local muscle temperature increased over the first 5 min of cycling.

The effect of local tissue temperature on high-intensity sprinting exercise is equivocal. Ftaiti *et al.* (2001) found no effect of exercise-induced hyperthermia on isokinetic maximal contractions at $4.20\ \mathrm{rad \cdot s^{-1}}$. Power output and integrated EMG signals have been shown to be decreased during intermittent 60 s sprints in hot and humid conditions (Kay *et al.*, 2001). However, this may have been due to psychological factors, as the power output and integrated EMG of the final sprint returned to similar values as during the first sprint. The lack of change in power output despite a progressive increase in core temperature in these studies and the present protocol during both control and pre-cooling conditions is in contrast to the results of Ball *et al.* (1999), who reported a substantial increase in both peak and mean power output during a 30 s maximal sprint from a standing start after 30 min of exposure to a warm (30°C, 55% relative humidity) environment. These increases were primarily due to an increase in average pedalling cadence over the first portion of the sprint, and the higher cadence would suggest that local or whole-body temperature may have an influence on power output, possibly through the preferential recruitment of fast-twitch fibres (Ball *et al.*, 1999). Unfortunately, no temperature parameters of any kind were recorded for the participants in the study of Ball *et al.* (1999), and it is debatable whether their heating protocol of 30 min of passive sitting in a warm environment would have had a substantial effect on core or leg temperature. However, if an elevated local leg muscle temperature is effective in increasing power output – as reported by Sargeant (1987) with local leg heating and cooling before isokinetic sprints and by Stewart *et al.* (2003) with elevations in leg muscle temperature of 3°C with an active warm-up before squat jumps – then the ideal pre-cooling protocol for repeated sprint performance might consist of upper-body cooling combined with either passive or exercise-induced active warming of the active musculature.

Interestingly, the lack of a benefit of either whole-body (Sleivert *et al.*, 2001) or upper-body pre-cooling on Wingate sprinting appears to differ from the effects of hyperthermia on isometric maximal exercise, where a significant decrease in maximal voluntary contractile force was reported with hyperthermia. Nybo and Nielsen (2001a) induced hyperthermia using cycling in the heat and found significant increases in the decay of voluntary motor activation for both isometric knee extension and handgrip. In addition, interpolated twitch data from our laboratory support a progressive decrease in voluntary motor activation for knee extension with increasing core temperature (Morrison *et al.*, 2004). In the present study, rectal temperature increased by 1.2–1.3°C over the 30 min of exercise in both the control and pre-cooling conditions with no effects on power output, suggesting no effect of elevated body temperature on maximal force generation in a dynamic setting. However, the difference may be due to the lower absolute core temperatures achieved with our protocol, where participants attained a final rectal temperature of 38.1 ± 0.8°C in the control condition and 37.8 ± 0.3°C in the pre-cooling condition, in contrast to the 40 ± 0.1°C obtained by Nybo and Nielsen (2001a). This higher level of hyperthermia may have elicited greater central fatigue, including decreased mental arousal (Nielsen *et al.*, 2001) and cerebral blood flow velocity with hyperthermia (Nybo and Nielsen, 2001b; Nybo *et al.*, 2002), which may only be evident upon reaching a critical threshold of hyperthermia (Pilcher *et al.*, 2002). In addition, the use of dynamic cycling in the present protocol may have elicited different patterns of motor unit recruitment compared to isometric maximal contractions (Gamet *et al.*, 1990; Sogaard *et al.*, 1998), making comparisons difficult.

In summary, mild upper-body pre-cooling of the body for up to 75 min resulted in an initial lower core temperature of 0.5°C and lower mean skin and mean body temperatures throughout 30 min of submaximal cycling in a moderate (22°C) ambient temperature, but had no effect on the peak and mean power output during intermittent supramaximal cycling sprints. This occurred even with a pre-cooling protocol designed specifically to minimize the local cooling of the active leg musculature, and suggests that, unlike prolonged submaximal exercise, pre-cooling may have a limited ergogenic benefit for high-intensity sprint exercise.

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