Precooling, Exertional Heatstroke Risk Factors, and Postexercise Cooling Rates

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BACKGROUND: Precooling (PC) before exercise may help prevent severe hyperthermia and exertional heatstroke (EHS). Before clinicians can advocate PC as an EHS prevention strategy, it must effectively mitigate factors associated with EHS development while not lessening the effectiveness of EHS treatment. Therefore, this study determined if PC affected rectal temperature (T_{rec}), body heat storage, heart rate (HR), ratings of perceived exertion (RPE), thermal sensation, sweat rate, and postexercise cold-water immersion (CWI) T_{rec} cooling rates.

METHODS: In this randomized, crossover, counterbalanced study, 12 subjects (6 men, 6 women; age = 22 ± 2 yr; mass = 73.5 ± 7.9 kg; height = 171 ± 7 cm) underwent 15 min of CWI (10.0 ± 0.03°C) in an environmental chamber (38.6 ± 0.6°C; 36 ± 2% humidity). After a 10-min rest, they exercised to a T_{rec} of 39.5°C. Subsequently, they underwent CWI (9.99 ± 0.03°C) until T_{rec} reached 38°C. On control (CON) days, the same procedures occurred without the 15-min PC intervention. T_{rec}, HR, thermal sensation, and RPE were measured at various times before, during, and after exercise.

RESULTS: PC lowered body heat storage and T_{rec} by 15.7 ± 15.0 $W \cdot m^{-2}$ and 0.42 ± 0.40°C, respectively, before exercise. Subjects exercised significantly longer (PC = 66.7 ± 16.3 min, CON = 45.7 ± 9.5 min) and at lower T_{rec} (~0.5 ± 0.5°C) and HR (~10 ± 7 bpm) following PC. PC significantly lowered sweat rate (PC = 1.02 ± 0.31 $L \cdot h^{-1}$, CON = 1.22 ± 0.39 $L \cdot h^{-1}$), but did not affect RPE or CWI cooling rates (PC = 0.18 ± 0.14°C $\cdot min^{-1}$; CON = 0.19 ± 0.05°C $\cdot min^{-1}$). Thermal sensation significantly differed between conditions only at pre-exercise (PC = 3 ± 1, CON = 5 ± 0.5).

DISCUSSION: PC delayed severe hyperthermia and mitigated dehydration without affecting thermal perception or cooling rates posthyperthermia. PC may help prevent dangerous hyperthermia in athletes.

KEYWORDS: dehydration, heart rate, rectal temperature, thermal sensation.

Wohlfert TM, Miller KC. *Precooling, exertional heatstroke risk factors, and postexercise cooling rates*. Aerosp Med Hum Perform. 2019; 90(1):12–17.

Exercising in hot and humid conditions inhibits the body's ability to dissipate heat through evaporative heat loss. If heat production exceeds heat loss, body temperature will increase and individuals may develop exertional heat illnesses like exertional heatstroke (EHS). In athletes, EHS continues to be a serious life-threating condition that necessitates the use of effective prevention strategies.[5] Current EHS prevention strategies include pre-participation screenings for EHS risk factors; implementation of climate-based acclimatization and work-rest schedules; and maintaining euhydration during exercise.[5]

Precooling (PC) with whole-body cold-water immersion (CWI) may help prevent exercise-induced hyperthermia or EHS by offering several advantages for athletes who exercise in the heat. First, PC lowers body core temperature, thereby increasing body heat storage capacity.[18,24,31] Second, PC lowers skin temperature, thereby increasing the core to skin temperature gradient; this may facilitate heat loss from the core.[7] Third, PC prolongs the onset of hyperthermia-induced fatigue[2] while also reducing heart rate at a given exercise intensity.[21,27] Fourth, PC causes vasoconstriction of superficial blood vessels, which would decrease skin blood flow[14] and increase stroke volume.[11] Finally, PC may decrease sweat rates,[3,28] which could reduce an athlete's risk of developing severe hyperthermia from dehydration.[20]

Despite the possible benefits of PC, its usefulness as a preventative measure against hyperthermia and EHS requires two main points of clarification. Since PC elicits some physiological effects which affect body heat storage (e.g., reduced sweating,

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This manuscript was received for review in June 2018. It was accepted for publication in October 2018.

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DOI: https://doi.org/10.3357/AMHP.5194.2019

delayed onset of sweating, vasoconstriction of cutaneous blood vessels),[8,30] it is possible PC could affect CWI cooling rates of hyperthermic athletes. Before PC can be recommended as a safe EHS prevention strategy, data must confirm that it does not impair CWI cooling rates or have cooling rates lower than 'ideal' for treating EHS victims (i.e., $< 0.16°C \cdot min^{-1}$).[19] Second, PC may interfere with an individual's ability to assess how hard they are exercising or how hot they feel (i.e., thermal sensation).[14] Consequently, athletes may exercise longer or at higher intensities, which could also increase their risk of developing severe hyperthermia or EHS.

The purpose of our study was threefold. First, we wanted to determine if PC affected several factors associated with hyperthermia or EHS, including hydration status, rectal temperature (T_{rec}) during exercise, and perceived exercise intensity (RPE). Second, we questioned if PC affected perceptual measures of temperature such as thermal sensation.[32] Finally, we wanted to know if PC altered postexercise CWI cooling rates of hyperthermic humans. We hypothesized PC would delay the onset of sweating, thereby resulting in better hydration status; PC would lower T_{rec}, thermal sensation, and RPE for the first 15 min of exercise; and PC would increase postexercise CWI cooling rates due to higher body heat storage during exercise.[1] Accomplishing these objectives would go far in determining if PC could be used as an effective prevention strategy for EHS or severe hyperthermia.

METHODS

Subjects

We recruited a convenience sample of 15 healthy, physically active, unacclimatized men and women to complete this randomized, counterbalanced, crossover study. We discontinued testing on two subjects due to equipment malfunctions and one subject due to an intolerance to the exercise protocol. Thus, 12 subjects completed the study (**Table I**). Women were tested during the follicular phase of menses to minimize hormonal effects on body temperature.

Volunteers were excluded from participating if they self-reported: 1) an injury which impaired their ability to exercise; 2) any diagnosed or untreated neurological, respiratory, or cardiovascular disease; 3) taking any medications (e.g., diuretics) that may have affected fluid balance or temperature regulation; 4) a sedentary lifestyle (defined as exercising < 30 min, 3 times per week); 5) a history of heat-related illness (e.g., heat exhaustion) in the 6 mo preceding data collection; 6) illness at the time of data collection; 7) cold allergy; or 8) pregnancy. Our university's institutional review board approved all procedures and subjects provided written consent before beginning the study.

Equipment

Pretesting hydration status was assessed with a hand-held refractometer (Model SUR-Ne; Atago USA Inc., Bellevue, WA). Body mass was measured to the nearest hundredth of a kilogram (Defender 5000; Ohaus Corp, Parsippany, NJ). Skinfold thickness was measured using a baseline skinfold caliper (model 12-1110; Fabricated Enterprises, Inc., White Plains, NY). Heart rate was monitored using a heart rate monitor (model FT1; Polar Electro Inc., Lake Success, NY). Rectal temperature was measured using an indwelling thermistor at a depth of 15 cm past the anal sphincter (YSI 4600 precision thermometer with #401 probe; Advanced Industrial Systems Inc, Prospect, KY). Environmental chamber temperature and humidity were monitored using a Kestrel Heat Stress Tracker (model 4400; Nielsen-Kellerman, Boothwyn, PA). Subjects exercised on a treadmill (model 1850; Proform Performance, Logan, UT). A 1135.6-L capacity, noncirculating water tub (model 4247; Rubbermaid, Atlanta, GA) was used for all water immersions.

Table I. Subject Demographics and Descriptive Information.

	CONTROL	PRECOOLING
Demographics		
Age (yr)	22 ± 2	
Height (cm)	171.0 ± 6.8	
Body Mass Index	25.2 ± 3.5	
Body Density ($g \cdot cc^{-1}$)	1.07 ± 0.01	
Body Fat (%)	12 ± 6	
Body Surface Area (m^2)	1.9 ± 0.1	
Hydration Measurements		
Pre-exercise U_{sg}	1.003 ± 0.003	1.005 ± 0.006
Body Mass Pre-exercise (kg)	73.3 ± 7.8	73.5 ± 8.0
Body Mass Postexercise (kg)	72.4 ± 7.7	72.4 ± 7.8
Sweat Rate ($L \cdot h^{-1}$)*	1.22 ± 0.4	1.02 ± 0.31
Posttesting Hypohydration (%)†	1.3 ± 0.5	1.5 ± 0.6
Water Bath Temperatures (°C)		
Before Precooling		10.01 ± 0.03
After Precooling		10.77 ± 0.12
Before Postexercise CWI	9.99 ± 0.03	10.0 ± 0.03
After Postexercise CWI	10.6 ± 0.14	10.6 ± 0.17

Data are means ± SD, $N = 12$. CWI = cold water immersion, U_{sg} = urine specific gravity. * PC < Control. †PC > Control. All superscripts indicate a difference between conditions ($P < 0.05$).

Procedures

Subjects reported for testing on 2 d at approximately the same time of day and at least 48 h apart. Subjects were instructed to wear the same or similar clothing each testing day, avoid exercise, stimulants (e.g., caffeine), or depressants (e.g., alcohol) for 24 h before testing, maintain a normal diet, drink water consistently the day preceding testing, and fast for 2 h before testing. Compliance was self-reported prior to each testing session.

Before testing, subjects voided their bladders completely and we assessed urine specific gravity. If urine specific gravity indicated the participant was hypohydrated (i.e., > 1.02), they were rescheduled for a later testing date and time. In the current study, none of our subjects required rescheduling due to dehydration. Subjects who were euhydrated were weighed nude. We measured skinfold thickness in triplicate at the chest, abdomen, and thigh (men) or posterior arm, thigh, and abdomen (women).[22] Skinfolds were averaged at each site and used to estimate body density[13] and percentage of body fat.[29] Body surface area was estimated using the Dubois and Dubois equation[9] (Table I).

Subjects donned a heart-rate monitor and inserted a rectal thermistor. Subjects dressed in underwear, shorts, socks, and a t-shirt before entering an environmental chamber (38.6 ± 0.6°C; 36 ± 2% humidity). Then we recorded subjects' T_{rec}, thermal sensation, and RPE.[4]

On the control day (CON), subjects stood on a treadmill for 10 min to acclimate to the hot conditions. Then they reported thermal sensation and RPE. On the PC day, subjects entered a water tub (9.99 ± 0.03°C) and immersed themselves up to their neck for 15 min. We chose to precool for 15 min because this resulted in T_{rec} afterdrops of ~0.5°C during pilot testing, which were consistent with prior literature[3,30] and this duration did not pose a risk of hypothermia to subjects. Furthermore, we used whole-body immersion to precool the subjects for three reasons: 1) it is the gold-standard method for treating EHS;[5] 2) the equipment would likely be onsite already for EHS treatments; and 3) it has the highest T_{rec} cooling rates of all cooling modalities.[19]

We stirred the water bath every 2 min with a metal rod and instructed subjects to notify us if they started shivering in any body part. The water bath was kept in the environmental chamber to minimize transfer time and to simulate the ambient conditions that an athlete might experience while at an outdoor athletic event in the heat. Following PC, subjects were given 10 min to change into dry clothes. Then we recorded subjects' T_{rec}, thermal sensation, and RPE.

Subjects then began our exercise protocol, which consisted of walking for 3 min at 4.8 km/h (3 mph) and then running at 90% of their age-predicted maximal heart rate (HR) for 2 min at 0% incline. To achieve their age-predicted target HR during the running portion of the exercise bouts, subjects chose a treadmill speed that they thought was challenging. Then we adjusted treadmill speed, as necessary, so their HR was close to their age-predicted target HR (± 5 bpm). HR was measured every 5 min during exercise. RPE and thermal sensation were measured every 10 min during exercise. This walking-running protocol was repeated, with no breaks, until T_{rec} reached 39.5°C (a frequently used T_{rec} for studying cooling interventions following exercise-induced hyperthermia). We used this exercise protocol because it is challenging, but tolerable, for recreationally active individuals. Furthermore, most of the subjects in our prior studies achieved the hyperthermic threshold of 39.5°C within 60 min. While subjects exercised, we monitored water bath temperature and maintained it at ~10°C by adding ice as necessary, making sure all ice had melted prior to subjects entering the bath.

Once T_{rec} reached 39.5°C, thermal sensation was recorded. Subjects stopped exercising, stepped off the treadmill, removed only their shoes, and immediately immersed themselves up to the neck in a noncirculating water tub until T_{rec} was 38°C. The water bath was stirred every 2 min. Subjects' T_{rec} was continuously monitored and they were instructed to tell us if, and when, they started shivering. The exact time to reduce T_{rec} to 38°C was noted. Subjects exited the water bath and reported their thermal sensation. They sat in the heat for 15 min for recovery purposes. Following the recovery period, subjects exited the environmental chamber, removed the rectal thermistor, towel dried, were weighed nude a second time, and were excused. No fluids were given to them at any time during testing.

Statistical Analysis

Data were assessed for skewness, kurtosis, and omnibus normality to ensure normal distribution. CWI T_{rec} cooling rates and percent hypohydration were evaluated using the nonparametric Wilcoxon signed-rank test due to the violation of statistical normality. Separate dependent *t*-tests were used to determine if differences existed between conditions for sweat rates, exercise durations, overall body heat storage rates, and CWI durations. CWI T_{rec} cooling rates were calculated from CWI durations. Body heat storage was calculated using body mass, T_{rec}, and body surface area.[26]

Separate repeated measures analyses of variance (ANOVA) were used to determine if differences in T_{rec}, RPE, HR, thermal sensation, or body heat storage existed between conditions over time. Upon significant interactions, Tukey-Kramer post hoc tests identified differences between conditions within each time point. Sphericity was assessed with Mauchly's test. Geisser-Greenhouse adjustments to *P*-values and degrees of freedom were made when sphericity was violated.

We did not examine simple main effects (e.g., time) as these did not address our research questions. Moreover, since differences between and within subjects existed for several variables between days (e.g., exercise and cooling times), we statistically analyzed data common to all subjects on each day. Significance was accepted when $P \leq 0.05$ (Number Cruncher Statistical Software v.2007; Kaysville, UT).

RESULTS

All data are means and standard deviations with the exception of CWI T_{rec} cooling rates and percent hypohydration, which are reported as medians and interquartile ranges. Subjects' pretesting hydration and water bath temperatures were consistent each day (Table I).

Precooling decreased subjects' T_{rec} by 0.42 ± 0.40°C before the onset of exercise, which resulted in significant differences between conditions for body heat storage [$F(2,25) = 10.1$, $P < 0.001$]. Body heat storage pre-exercise (PC = −15.7 ± 15.1 $W \cdot m^{-2}$; CON = 1.8 ± 1.9 $W \cdot m^{-2}$) and at 5 min into exercise (PC = −6.0 ± 7.3 $W \cdot m^{-2}$; CON = 4.9 ± 3.0 $W \cdot m^{-2}$) were lower with PC than CON ($P < 0.05$). While differences in body heat storage were transient, overall body heat storage rate for the entirety of exercise was different [$t(11) = 7.5$, $P < 0.001$; PC = 1.29 ± 0.33 $W \cdot m^{-2} \cdot min^{-1}$, CON = 1.92 ± 0.47 $W \cdot m^{-2} \cdot min^{-1}$]. Of the 12 subjects, 8 (67%) self-reported shivering during PC; average self-reported shivering onset was 3.9 ± 1.2 min.

Excluding the pre-intervention measurement, PC T_{rec} was lower than CON T_{rec} for the entirety of exercise [$F(2,25) = 21.3$, $P < 0.001$; **Fig. 1**]. Consequently, PC prolonged the time

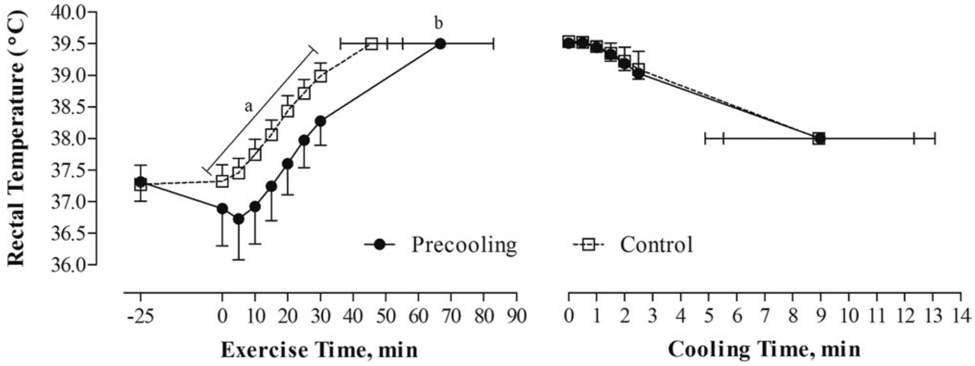

Fig. 1. Rectal temperatures during exercise (left) and cold-water immersion (CWI, right) (means ± SD, $N = 12$). X-axis error bars indicate the SD for the final exercise and CWI durations. Time 0 indicates the start of exercise. [a]Precooling < Control ($P < 0.05$). [b]Precooling exercise duration longer than control exercise duration ($P < 0.001$).

necessary for subjects' T_{rec} to reach 39.5°C by 21.05 ± 10.94 min [$t(11) = 6.7$, $P < 0.001$; Fig. 1]. The prolonged exercise times after PC likely caused the higher levels of hypohydration in the PC condition ($Z = 2.8$, $P = 0.001$) since PC sweat rates were significantly lower than CON sweat rates [$t(11) = 5.2$, $P < 0.001$, Table I].

We observed an interaction between condition and time for HR [$F(2,26) = 4.3$, $P = 0.02$; **Fig. 2**] and thermal sensation [$F(3,28) = 14.3$, $P < 0.001$; **Fig. 3**]. PC significantly lowered HR for the first 20 min of exercise ($P < 0.05$; Fig. 2). Thermal sensation on the PC days was only lower than CON at the pre-exercise time point ($P < 0.05$; Fig. 3). In contrast, we did not observe an interaction between condition and time for RPE [$F(2,22) = 1.1$, $P = 0.34$]; RPE was similar between conditions at all time points during exercise (Fig. 2, $P > 0.05$).

For T_{rec} during the postexercise CWI, we did not observe an interaction between condition and time [$F(1,12) = 0.2$, $P = 0.7$; Fig. 1]. CWI duration was similar between PC and CON [$t(11) = 0.04$, $P = 0.49$; Fig. 1]. Consequently, T_{rec} CWI cooling rates were similar between conditions (PC = 0.18 ± 0.14°C · min^{-1}; CON = 0.19 ± 0.05°C · min^{-1}, $Z = 0.47$, $P = 0.34$). For the postexercise CWI, 6 of 12 subjects (50%) shivered on PC days with a self-reported shivering onset of 5.7 ± 2.5 min. For CON, only two subjects (17%) self-reported shivering during the postexercise CWI with a shivering onset of 5.0 ± 1.7 min.

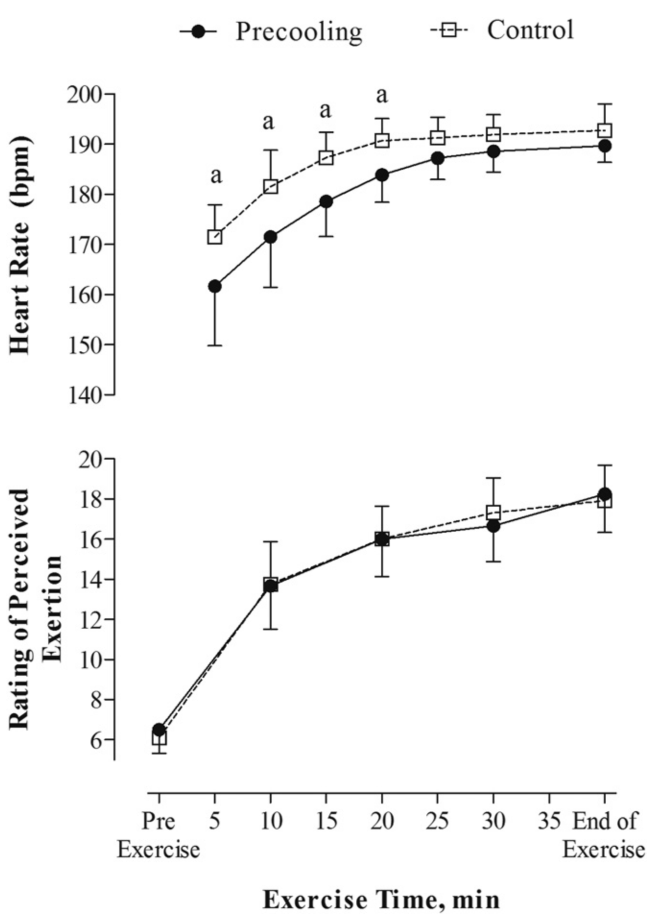

Fig. 2. Heart rates and ratings of perceived exertion (RPE) during exercise with and without precooling (means ± SD, $N = 12$). The end of exercise data points were the last heart rates and RPE recorded during exercise for each subject on each testing day. [a]Precooling < Control ($P < 0.05$).

DISCUSSION

PC may be a useful strategy to prevent dangerous exercise-induced hyperthermia and possibly EHS. We observed PC reduced T_{rec} and body heat storage before exercise. While these effects were short lived, the rate of heat storage for the duration of exercise was lower in the PC trial. Consequently, subjects

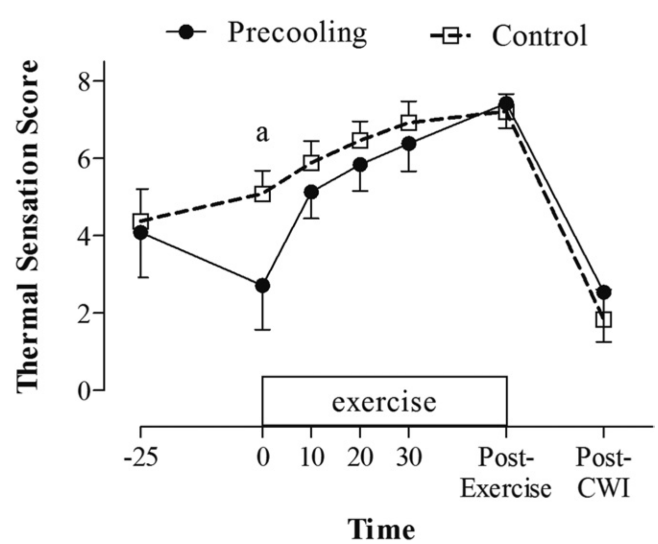

Fig. 3. Thermal sensation before, during, and after exercise with or without precooling (means ± SD, $N = 12$). Scale ratings ranged from 0 (unbearably cold) to 8 (unbearably hot). A score of 4 indicated subjects were "comfortable." [a]Precooling < Control ($P < 0.05$).

were able to exercise ~20 min longer before their T_{rec} reached 39.5°C. These observations were consistent with other studies.[3,8,30] Some authors[30] observed gastrointestinal temperature dropped 0.5 ± 0.4°C after 15 min of PC in 10 ± 1°C water. Others reported body core temperature decreases of 0.7 ± 0.1°C[3] to 1.0 ± 1.0°C[8] with longer PC durations (e.g., 60 min) and warmer water bath temperatures (e.g., 20°C to 29°C). Our observation that PC delays the onset of hyperthermia expands upon the work of other authors who noted PC increased subjects' running time to ventilatory exhaustion[28] and maximum running distance in time trials.[3] Therefore, PC may be able to improve exercise performance while also delaying the onset of hyperthermia and, possibly, heat illness. These attributes could be helpful for athletes who compete in hot and humid environments and have a higher risk of exertional heat illnesses.

PC did not influence T_{rec} cooling rates after subjects became hyperthermic. Postexercise CWI cooling rates were likely unaffected because PC effects are short lived[30] and we used the same thermal threshold to terminate exercise. However, T_{rec} cooling rates in our study were excellent and exceeded the recommended cooling rate (i.e., $0.16°C \cdot min^{-1}$) for athletes who experience EHS.[19] Clinically, this means if an athlete was precooled before exercise but later developed dangerously high T_{rec}, the PC would not impair the effectiveness of CWI as a treatment. These data remove the concern that PC may interfere with the treatment of athletes who develop hyperthermia. However, we can only speculate on how PC would affect CWI T_{rec} cooling rates in athletes with actual heat illnesses.

PC also mitigated fluid lost while also lowering HR during exercise. In our study, PC reduced sweat rate by $0.2 \ L \cdot h^{-1}$. Siegel et al.[28] also observed lower sweat rates following PC ($1.8 \pm 0.5 \ L \cdot h^{-1}$) compared to their control condition ($2.3 \pm 0.6 \ L \cdot h^{-1}$). Since sweating onset is triggered by increases in body core temperature and PC reduced T_{rec}, it is likely sweat initiation was delayed. Moreover, some authors observed greater evaporation of sweat following PC, which resulted in more economical evaporative heat dissipation.[16] By reducing dehydration and improving sweat evaporation, PC may help reduce the risk of athletes developing severe hyperthermia.[20]

Similarly, we observed HR was lower (~10 bpm) for the first 20 min of exercise following PC. Booth et al.[3] reported PC lowered HR by 10% during the first 10 min of running. Siegel et al.[28] reported HR was lower by 8 ± 5 bpm for the first 35 min of exercise in the PC condition compared to their control. Differences in HR between studies were likely due to the discrepancies in PC parameters such as water temperature and duration. A colder water bath temperature and longer duration would likely increase the extent of cutaneous vasoconstriction. This may have improved cardiac filling and increased ventricular stroke volume to the working muscles, allowing for sustained cardiac output at a lower HR. Lower sweat rates during the PC conditions may have also influenced HR. Since less fluids were lost to dissipating heat through the evaporation of sweat, blood plasma levels were likely higher, which may have also increased stroke volume and reduced the HR necessary to maintain cardiac output during exercise.

While PC affected several physiological variables, it did not alter perceptions of exercise intensity or thermal sensation. RPE can be influenced by environmental conditions, exercise intensity, age, and psychological factors.[25] Since these factors remained consistent in our study, the lack of differences in RPE between conditions was not surprising. While PC can reduce skin temperature by 14°C, it returns to nadir quickly following the onset of exercise.[30] The lack of differences in perceptual variables like thermal sensation were likely because the effects of PC were short lived and comparable to the control day.[3,8,30] Overall, these data demonstrate PC with CWI has a minimal effect on subjects' ability to perceive how hard they are exercising or how they feel. Thus, clinicians need not worry that PC will predispose athletes to heat illnesses by affecting their perception of body temperature or exertion intensity.

Before implementing PC in athletic populations, clinicians should consider water bath temperature,[23] immersion duration,[33] athlete anthropometrics,[10] and sport-specific skill requirements. Anecdotally, we observed T_{rec} rarely decreased while subjects were being precooled. The maintenance of T_{rec} during PC was likely because of the vasocontriction of cutaneous blood vessels, shunting of blood from the periphery to the core, and shivering.[6] T_{rec} afterdrop in our study ranged from 0.1°C to 1.1°C, which is consistent with other authors using similar water bath temperatures and immersion durations.[8] Thus, athletes with low adiposity, higher body surface areas, and/or higher body surface area to lean body mass ratios may be more prone to afterdrop and, consequently, hypothermia.[10] Consequently, clinicians must carefully select PC parameters before implementing PC. Finally, while PC may be beneficial for running performance,[3,28] it may impair fine motor skills, which could be detrimental in some sports (e.g., tennis, baseball). If, and how long, PC affects performance in sports requiring high amounts of fine motor skills is unknown.

Our study had three main limitations. First, we used HR to monitor and control exercise intensity. Like other authors,[3,28,30] we observed noticeable decreases in HR during exercise. Thus, many of our subjects were unable to achieve 90% of their age-predicted maximal HR during the first 20 min of exercise on the PC day. Thus, it is possible our subjects exercised at higher intensities on PC days as they attempted to increase their HR to comply with our instructions. We do not believe this significantly affects our interpretation of the present data since no differences in RPE occurred between conditions and we still noted significant differences in HR, sweat rate, exercise duration, and T_{rec} between conditions. Given this limitation, it is possible PC effects last longer and/or are more beneficial than reported in this study. A second limitation was the lack of skin temperature measurements during testing. Future studies should measure skin temperature before, during, and after PC to ascertain how PC affects heat flux as subjects exercise to hyperthermic thresholds. The third limitation of our study was our subjects did not have the anthropomorphic characteristics of athletes most prone to heat illness (e.g., high body fat percentages, low body surface area to lean body mass ratio).[12] Future studies should evaluate the efficacy of PC for exertional heat illness prevention in athletes with the anthropomorphic characteristics of athletes most at risk of EHS. Finally, thermoregulatory factors (e.g., sweat responses)[15] and anthropomorphic differences exist between the sexes, which may affect cooling rates.[17] While we controlled for menstrual cycle phase, our sample size did not allow for an in-depth analysis of how PC may have been influenced by sex. Future studies may wish to explore possible interactions between sex and PC in larger samples of men and women.

In summary, we demonstrated several physiological benefits of PC that may be helpful for the prevention of severe hyperthermia and exertional heat illnesses. Most importantly, PC provided these benefits without affecting T_{rec} CWI cooling rates once subjects became hyperthermic. For these reasons, clinicians may wish to add PC to the list of other effective heat illness prevention strategies so long as they consider and implement safe and effective PC parameters for their athletes.

ACKNOWLEDGMENTS

We thank Central Michigan University's Office of Research and Graduate Studies for partially funding this study as well as Jake Taylor and Michael Szymanski for their help with data collection.

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