RESEARCH ARTICLE

Precooling with an ice vest: Effect on core temperature in collegiate female swimmers

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Abstract

Precooling has been shown to improve athletic performance, delay core heating, and decrease heartrate in cyclists and runners, but very little research has observed core temperature (CT), rate of perceived exertion (RPE) and heartrate (HR) response to precooling in collegiate female swimmers.

Purpose: The purpose of the current study was to observe the effect of precooling on CT, RPE, and HR while swimming 1600-yards.

Methods: Eleven female collegiate swimmers participated in randomized crossover swimming trials with and without precooling. Trials were separated by one week with each subsequent trial performed at the same time of day in the same pool and lane set-up with a water temperature of 26.1° C. Subjects rested for 30 min while wearing an ice vest and wet t-shirt in precooling trials. All trials included the same 15 minute warm up followed by 1600-yards at 75% of their individual fastest mile pace. CT, RPE and HR were recorded before and after warm up, and at 100-yard intervals.

Results: Average group precooling CTs were significantly lower (37.88±4° C) than the control condition (38.17±.19° C, P=.02) throughout the test. Group precooling HRs were not significantly different (P=.20), however seven of the 11 subjects did present lower HRs during the precooling trial. Group RPEs were not significantly different between conditions (P>.05), although six subjects presented significantly higher RPEs in the precooling condition (P<.05).

Conclusion: Precooling using an ice vest 45 min prior to exercise was shown to significantly reduce CT during swimming compared to no precooling. HR and RPE varied between subjects, suggesting that athletes respond differently both physiologically and psychologically to precooling. Coaches should consider individual variation and experiment prior to competition to determine whether precooling can improve performance in a 1600-yd swim.

1. Introduction

Physiologic mitigation of excess heat is accomplished through a complex system designed to monitor core temperature (CT) and attenuate work as needed to prevent heat illness.[1] Hyperthermia results when metabolic heat production exceeds the body's ability to dissipate heat. Exercise induced hyperthermia and the accompanying physiologic changes are frequently cited as primary reasons for diminished exercise capacity. Research shows excess heat accumulation decreases maximal oxygen consumption,[2,3,4] reduces time to exhaustion during exercise,[5] and increases cardiovascular strain. [3] Voluntary muscular contraction is impaired with an elevated CT (≈40° C) in both exercising and non-exercising muscles,[6,7] however, the ability of the muscle to generate force is not compromised, suggesting that fatigue may be more related to the brain's ability to sustain activation of the skeletal muscles in a hyperthermic state.[6]

Elevated brain temperature may be a key limiting factor in exercise performance.[6,8,9] Given that brain temperature and CT rise at the same rate during prolonged exercise,[9] integrating practices designed to slow the rate of heat accumulation may be beneficial to performance. Research has shown that precooling decreases CT before beginning exercise. [2,8,10,11] This may aid exercise by increasing heat storage capacity, thereby extending the time it takes to reach a hyperthermic state.[2,12] Some research shows that CT is significantly lower (P=.03) after exercise with precooling compared with no precooling. [10]

Available literature shows that cooling prior to exercise improves performance in hot ambient environments while running or cycling,[8,10,12,13,14,15,16] however, there is little information available on the effect precooling has on swimming performance. The purpose of the current study was to observe the effect of precooling on CT, rate of perceived exertion (RPE) and heartrate (HR) while swimming 1600-yards.

2. Methods

2.1 Study Overview

A randomized, crossover design was used to examine the effect of precooling on swimming performance. Subjects completed a 1600-yd swim under two conditions in random order: 1) a precooling condition where subjects rested on the pool deck while wearing an ice vest and wet t-shirt prior to beginning warm up (COOL), and 2) a control condition where subjects did not participate in any precooling procedures (CON). Trials for individuals were separated by one week with each subsequent trial performed at the same time of day. All trials were performed in the same pool. Lane configuration and pool water temperature (26.1° C) remained constant for all trials.

2.2 Subjects

Eleven female NCAA DII collegiate swimmers were recruited as subjects. All swimmers were 21 years old. Subjects were highly trained distance swimmers.

2.3 Preparation for trials

All subjects were instructed to consume food and water as they normally would but refrain from alcohol and strenuous activity for at least 24 hours prior to testing.

Core temperature was measured with CorTemp pill sensors (HQ Inc. CorTemp, Palmetto, FL). A CorTemp data recorder (HQ Inc. CorTemp, Palmetto, FL, USA) was used for all CT readings. The subjects were required to ingest the sensor four to six hours prior to their scheduled trial time in order for the sensor

to be in the small intestine. They were then permitted to consume food and water normally until the beginning of the test.

A hand-held pulse oximeter (BCI, Waukesha, WI, USA) was used to measure HR. The Borg Rating of Perceived Exertion 6-20 scale was used to monitor RPE.[17]

At the time of the test, subjects arrived at the testing location wearing a racing suit of their choice and baseline CT and HR were recorded. Subjects in the CON group were then permitted to begin a prescribed 15 min warm up. Subjects in the COOL group put on a wet t-shirt and FlexiFreeze Ice Vest (FlexiFreeze, Maranda Enterprises, LLC, Mequon, WI, USA) and were instructed to rest on the pool deck for 30 min. At the end of this precooling process, CT and HR were recorded again, and these subjects were permitted to begin a prescribed 15 min warm up.

All subjects completed a 15 minute warm up in the pool consisting of 400-yd swim, 200-yd kick, four sets of 50-yd drill and a 200-yd cool down. At the end of this warm up, CT, RPE and HR were recorded.

2.4 Test Procedures

The primary exercise was a 1600-yd freestyle swim broken up into 16, 100-yd intervals with 10 seconds rest between intervals. Swimming speed was normalized to individual performance, where each subject swam at a pace equal to 75% of their fastest mile. At the end of each interval, subjects were required to sit on the side of the pool while their CT, RPE and HR were recorded. After the final measurements were recorded, subjects completed a 200-yd cool down.

2.5 Statistical Analysis

Group comparison were made using an unequal variance t-test to determine significance between conditions. Single subject comparisons were done with a paired t-test. Significance was set at $P<.05$.

3. Results

3.1 Core Temperature

Average group CT was significantly lower in the COOL condition compared with CON (37.9±.4 vs 38.2±.2° C, $P<.05$). Average individual CT was significantly lower for seven of the 11 subjects and significantly higher for one subject after precooling (Table 1; $P<.05$). Average group CT was significantly lower ($P<.05$) during the second half of the warm up, and remained significantly lower until midway through the test procedure in the COOL group (Figure 1). Average group CT was significantly lower at the end of warm up in the COOL group compared with CON (37.3±.5 vs 37.8±.3° C, $P<.05$), and at the end of exercise in the COOL group compared with CON, though this was not found to be significant (38.3±.4 vs 38.5±.3° C, $P>.05$). Average group CT continued to drop throughout the warm up. The lowest group CT was seen 6.9±5.0 min into exercise in the COOL condition, whereas CT was lowest 2±2.7 min into exercise in the CON condition.

3.2 Heart Rate

Average group HR was lower in the COOL condition compared with the CON condition, though not significantly (163±5 and 167±2, respectively; $P>.05$). Average individual HR was significantly lower for four subjects and significantly higher for three of the 11 subjects ($P<0.05$).

3.3 Rating of Perceived Exertion

There was no difference in average group RPE between conditions (13±8). Individual RPE was lower for three of the 11

subjects in the COOL condition, though not significantly (P>0.05). In the COOL condition, individual RPE was significantly higher for six subjects (P<0.05), and remained unchanged for one subject.

Table 1.
Average Core Temperature for CON and COOL Conditions by Subject

	Core Temperature		Norm Core Temperature	
Subject No.	CON	COOL	CON	COOL
1	38.0±.1	31.2±.1*	.2±.1	-.2±.1*
2	38.1±.1	38.0±.0*	.3±.1	-.1±.0*
3	37.9±.3	38.0±.4	.3±.3	.9±.4*
4	38.0±.2	38.6±.2*	.4±.2	.5±.2
5	38.5±.2	38.4±.2	.9±.2	.7±.2*
6	38.3±.4	37.8±.4*	1.1±.4	.9±.4*
7	38.3±.1	37.7±.3*	.9±.1	.5±.3*
8	38.3±.1	37.4±.4*	.5±.1	.3±.4
9	38.3±.4	37.9±.4*	1.0±.4	.9±.4
10	38.4±.3	37.8±.3*	1.0±.3	.4±.3
11	38.0±.3	37.8±.7	1.1±.3	.9±.7

Values are mean ± SD. Temperature in degrees Celsius. Where CON is control condition and COOL is pre-cooling condition. Norm Core Temperature is normalized to baseline CT.
*Conditions significantly different, *P*<0.05

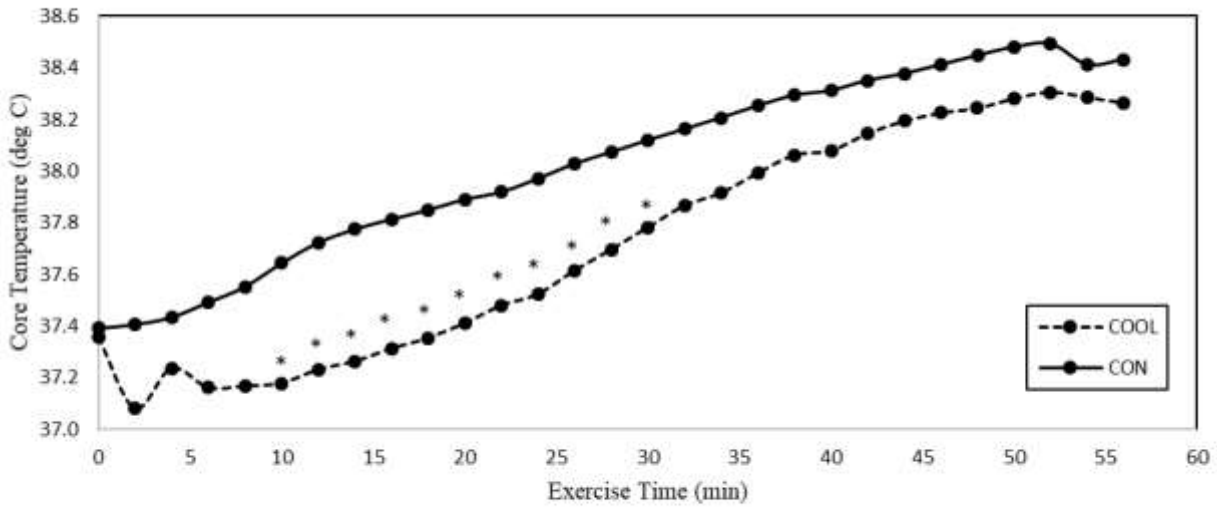

Figure 1. Core temperature during warm up, test trials, and cool down. Values are mean temperature for all subjects. *Significant difference between conditions, *P<.05*.

4. Discussion

This study examined the effect precooling with an ice vest has on CT, HR and RPE of swimmers in an indoor NCAA regulated competition pool. There is strong evidence that precooling improves exercise performance, with previous studies demonstrating marked performance improvements for runners and cyclists,[8,10,12,13,14,15,16] and another demonstrating improvements in swimming performance with intermittent cooling via cold water or ice ingestion.[11] However, there is very little available research examining how lowering CT before exercise effects swimming.

The present study demonstrated a significantly reduced average group CT in the COOL condition compared with CON (37.9±.4 and 38.2±.2° C, respectively; P<.05). This is consistent with previous research which shows that cooling vests are an effective tool for lowering CT.[10,12,13,15,16,18,] The majority of subjects (n=7, 64%) demonstrated a significantly lower CT after exposure to the ice vest (P<.05). This was not the case for one individual, however, who demonstrated a significantly higher average CT after cooling compared with control (38.6±.3° C vs 38.0±.2° C, P=.00). This discrepancy may be explained by the difference in initial CT before treatment as well as body composition. For this subject, the initial CT reading was significantly higher before beginning the cooling treatment than the initial CT reading in the CON condition (38.5° C vs 37.6° C, P=.00).

One recent study reported that CT continued to drop for several minutes into exercise. In our study, CT decreased throughout the warmup in the COOL condition, with the average group CT at its lowest 6.9±5.0 min into exercise.[19] Five subjects demonstrated a decrease in CT during the warm up in the CON condition, with the lowest average CT occurring at 4.4±2.2 min for these individuals. Average CT was lowest 2.0±2.7 min into exercise in the CON condition. Decrease in CT for the CON condition during the warm up is likely due to the effect of the pool water temperature. Thermoregulation is typically accomplished through the skin by radiation and evaporation, however while swimming heat is dissipated primarily through conduction. The thermal conductivity of water is demonstrably greater than air (0.00143 cal/sec/cm/° C and 0.000055 cal/sec/cm/° C, respectively), resulting in a more pronounced physiologic response to temperature.[20] Pool temperature was 26.1° C throughout the entirety of this study, which is within the National Collegiate Athletic Association (NCAA, 2017) regulations for swimming competition (26.1° to 27.2° C).[21] Body temperature can be influenced by environmental factors, so exposure to water that is colder than CT may contribute to the observed decrease in CT for the CON group.

Average group CT was significantly lower for the COOL condition compared with the CON condition at onset of exercise and after completing the warm up (P<.05). Although average CT was lower at the end of exercise in the COOL group, this finding was not significant (P>.05). This result differed from a recent meta-analysis which found that CT was significantly lower (P=.03) after exercise following a precooling protocol compared with controls.[10] The discrepancy here may be due to the difference in exercise environment, since the thermal conductivity of water is greater than air. The temperature of the water in which an individual is submerged has been shown to have a pronounced effect on rectal temperature changes,[20] though body composition and surface area may influence individual response. Body composition was not

measured in the current study, so the impact it may have had on CT response is unclear. Neither average group rate of change in CT (.0±.0° C/2 min for COOL and .0±.0° C/2 min for CON, P>.05) nor average group CT_{peak} (38.4±.4° C for COOL and 38.5±.3° C for CON, P>.05) differed significantly between conditions.

Research suggests that precooling and intermittent cooling improve exercise performance regardless of whether CT is lowered to below baseline levels.[13] This physiologic response to cold reduces cardiovascular strain by allowing blood pressure to stay constant with decreased HR and reduced blood plasma volume.[20,22] Intermittent cooling has been shown to significantly lower mean working HR,[18] however, the same response has not been demonstrated with precooling protocols.[12,16] In the current study, average group HR was lower in the COOL condition compared with the CON condition, though not significantly (163±5 vs 167±2, P>.05). Average individual working HR was lower for the majority of subjects (n=7, 64%), however, this result was only significant for four of them (36%, P<.05). The COOL condition did result in higher average working HR for four individuals, of these three were significant (P<.05). As reported in previous research,[8] the current study did not show a significant difference in HR_{peak} between conditions (180±12 and 180±8 bpm, for COOL and CON, respectively, P>.05).

There was no difference in average group RPE between conditions (13±8). This finding is confirmed in the literature.[8,12,23] Average individual RPE was lower for three of the 11 subjects in the COOL condition compared with CON, though not significantly (P>.05). By contrast, individual RPE was significantly higher for a majority (n=6, 55%) of subjects (P>.05). The cause of this result remains unknown; however, it may be related to the discomfort of precooling, especially when followed by immersion in tepid water. Physiologic responses to cold water immersion include increased cardiac workload and gasping (House & Tipton, 2015), which may explain the increased average RPE (n=7) and mean working HR (n=4) observed for subjects in the COOL condition.

5. Conclusion

This study demonstrated that precooling with an ice vest 45 min prior to exercise significantly reduces CT during swimming compared with no precooling. Individual response to HR between subjects was observed with majority of subjects responding with a decrease in mean working HR in the COOL condition. Coaches should consider individual variation and experience prior to competition to determine whether precooling can improve performance in competitive swimmers.

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