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Research article

Ice Ingestion Maintains Cognitive Performance during a Repeated Sprint Performance in The Heat

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Abstract

This study investigated the effects of precooling via crushed ice ingestion on cognitive performance during repeated-sprint cycling in the heat. Nine males, non-heat acclimatised to heat (mean age: 28.2 ± 2.7 y; height: 175.7 ± 9.7 cm; body-mass: 76.9 ± 10.6 kg) completed a 30 min bout of repeated-sprint (36 × 4 s sprints, interspersed with 56 s rest-breaks) on a cycle ergometer in a climate chamber (35°C, 70% relative humidity). Crushed ice ingestion ($7 g·kg^{-1}$, -0.4°C, ICE) or no cooling (CON) interventions were completed at rest, in the climate chamber, 30 min prior to exercise. Working memory was assessed via the serial seven test (S7) and the automated operation span task (OSPAN) at various time points before, during, and post-exercise. Core body temperature (T_c), forehead temperature (T_h), and thermal sensation (TS) were assessed throughout the protocol. Working memory significantly declined during exercise in CON as measured by S7 (p = 0.01) and OSPAN (p = 0.03); however, it was preserved in ICE with no change at the end of exercise in either S7 or OSPAN scores compared to baseline (p = 0.50, p = 0.09, respectively). Following precooling, T_h (-0.59°C, p < 0.001) and T_c (-0.67°C, p = 0.005) were significantly decreased in ICE compared to CON. At the end of the exercise, ICE significantly reduced T_c compared to CON (p = 0.03), but no significant differences were recorded for T_h. Further, TS was lower following precooling in ICE (p = 0.008) but not during exercise. In conclusion, ice ingestion significantly reduced T_h and T_c and facilitated maintenance of cognitive performance during repeated-sprint exercise in the heat, which may lead to better decision making.

Keywords: Precooling, cognitive function, team sport, forehead temperature.

Introduction

In team sports, many major competitions are carried out in hot and humid environments where ambient conditions can exceed 30°C and 70% relative humidity (RH). For example, more than 25% of football matches during the 2014 World Cup in Brazil were played under heat stress (Nassis et al., 2015), while the 2022 World Cup is scheduled to be played in Qatar, where ambient temperatures can average ~30°C. Exercising in hot and humid conditions increases core body temperature (T_c) and can increase cardiovascular strain (increased heart rate and decreased stroke volume; Periard et al., 2021). Notably, a $T_c \geq 38.5$°C (hyperthermia: Knochel and Reed, 1994) can result in the impairment or early termination of both endurance and repeated-sprint exercise (Drust et al., 2005; Girard et al., 2015; Gonzalez-Alonso et al.1999; Sunderland and Nevill, 2005). Further, the same T_c threshold is also used for clamped hyperthermia research by implementing a physiological controlled approach (fixed T_c during exercise, Periard et al., 2021). Although 38.5°C may represent a typical threshold, some people are able to withstand higher T_c and perform successfully (Racinais et al., 2019). Cognitive task performance relying on attention and working memory functions have also been reported to be impaired when $T_c \geq 38.5$°C (Bandelow et al., 2010; Hocking et al., 2001; Schmit et al., 2017), thus potentially limiting the ability of those affected to process information effectively during exercise (Kenefick et al., 2007).

Effective cognitive processing refers to the mind's ability to evaluate multiple pieces of information and then make appropriate decisions. This involves the limited-capacity systems of attention and working memory (Brown, 1996). Impairment in cognitive performance whilst exercising in the heat (Donnan et al., 2021) has been attributed to a reduction in cerebral blood flow (Nybo and Nielsen, 2001). This decrease in blood flow is likely due to blood being diverted to the periphery (for cooling) and the working muscles that extract oxygen from the blood for energy production (Falkowska et al., 2015). This can result in less oxygen and nutrients flowing to the brain, leading to transient cognitive impairment. Additionally, reduced cerebral blood flow may impair heat removal from the brain (Nybo et al., 2002), leading to increased brain temperature and potentially compounding cognitive deficits (Hocking et al., 2001).

Precooling has been used as a strategy to counteract the negative effects of heat on subsequent exercise and cognitive performance. Precooling has been found to be effective in reducing pre-exercise T_c, consequently delaying the onset of thermally induced fatigue by providing greater heat storage capacity (Zimmermann et al., 2017). This in turn has resulted in improved subsequent cognitive performance assessed before and after endurance exercise in the heat (Saldaris et al., 2019; 2020). Specifically, Saldaris et al. (2020) reported that working memory and decision-making were maintained pre and post 90 min of running at 65% $\dot{V}O2$peak in hot and humid conditions following precooling with $7 g·kg^{-1}$ of crushed ice ingestion, compared to no-cooling. These researchers suggested that crushed ice ingestion cooled the blood in the carotid arteries via conduction, which then flowed to the brain, thus cooling the brain. While benefit has been found for precooling on cog-

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nitive performance prior to and after endurance exercise, its impact in respect to repeated-sprint performance has not been well researched.

Compared to endurance exercise, prolonged repeated-sprint performance in the heat results in lower peak T_c (~38.5 versus ~40.0°C) and peak heart rate (~160 bpm versus ~170 bpm: Brade et al., 2013; Maroni et al., 2018, Maroni et al., 2019). These differences are most likely due to the inclusion of regular rest intervals during repeated-sprint performance (≤60 s per break; Girard et al., 2011), which may result in lower metabolic heat production, compared to endurance performance. Nonetheless, peak T_c during repeated-sprint performance can still become hyperthermic and exceed levels associated with cognitive impairment (i.e., 38.5°C). Thus, when exposed to hot ambient conditions, team-sport athletes may not be able to maintain a level of cognitive function needed to assist in accurate decision-making (Smits et al., 2014). To date, no studies have assessed the effect of precooling using ice ingestion on subsequent cognitive performance when performing repeated-sprints in the heat. Therefore, the aim of this study was to examine the effects of crushed ice ingestion (precooling) on cognitive function assessed prior to, during and after repeated-sprint exercise in hot and humid conditions. It was hypothesised that crushed ice ingestion would reduce T_c, T_h and subsequently maintain cognitive performance assessed at various time points when performing repeated-sprint exercise in the heat, compared to a no-cooling control.

Methods

Participants

Nine healthy, trained, team-sport athletes were recruited to this study (mean age: 28.2 ± 2.7 y; height: 1.76 ± 0.10 m; body-mass: 76.9 ± 10.6 kg; body surface area: 1.90 ± 0.17 m^2). All participants were informed of the details and requirements of the study. Written informed consent was provided from each participant prior to testing. Ethical approval was granted from the Human Research Ethics of Committee of the University (RA/4/20/6057).

Experimental overview

This cross-over study consisted of one familiarisation session and two experimental trials. All trials were performed at the same time of the day, one week apart. Experimental trials consisted of 30 min of repeated-sprint cycling (36 × 4 s sprints) preceded by 30 min of precooling where participants either ingested 7 $g \cdot kg^{-1}$ of crushed ice (-0.4°C; ICE), which had been crushed with a commercial ice crusher (Avalanche, Sunbeam, Australia), or ingested the same amount of room temperature tap water (35°C; CON). Trials were completed in a randomised order.

Familiarisation session

One week prior to the experimental trials, height (Seca, West Germany, Germany) and nude body-mass (model ED3300; Sauter Multi-Range, Ebingen, West Germany) were recorded. Participants were familiarised with the cognitive tasks (automated operation span test; OSPAN and serial seven test; S7), perceptual response scale (thermal sensation), and completed the 30 min repeated-sprint cycling protocol in the climate chamber (35°C, 70% RH).

Experimental protocol

Participants refrained from any strenuous exercise, ingestion of alcohol and caffeine 24 h prior to each testing session. During the same 24 h period participants recorded food and physical activities into personal diaries and then followed the same diet and activity regime prior to the subsequent experimental trial. Participants ingested a telemetry capsule (CorTemp®, Palmetto, FL, USA) eight hours prior to each trial to assess T_c.

Upon arrival to the laboratory, a mid-stream urine sample was collected to determine participants' hydration levels (TE-RM10SG, 1.000-1.070, Test Equip, Dandenong, Australia) via urine-specific gravity. If hypohydration occur ($U_{SG} > 1.030$), participants then consumed an additional 500 ml of water. No participants were found to be hypohydrated (i.e., USG > 1.030). A skin thermistor (Skin Sensor SST-1, Physitemp Instruments Inc, NJ, USA) was taped to the middle of the forehead, to assess forehead temperature (T_h) via a computerised program (DASYLab Light, National Instruments, Ireland Resources Ltd., USA).

Participants then entered the climate chamber (35°C, 70% RH) and completed the OSPAN test (10 min) and the S7 test (1 min) in a seated position. Participants remained seated and undertook either experimental intervention (crushed ice ingestion, ICE or ingested tap water, CON) 30 min prior to exercise. Participants completed the S7 test again after the rest period. The exercise trials began with a standardised 5 min cycling warm-up that included 2 x 4 s maximal sprints at 3.5 and 4.5 min followed by the 30 min repeated-sprint protocol.

The repeated-sprint protocol comprised of 30 x 4 s maximal sprints every 1 min (4 s sprint followed by 56 s active recovery ranging at 25 - 100 W). Additionally, six maximal 4 s sprints were performed at 2.5, 7.5, 12.5, 17.5, 22.5, 27.5 min to replicate the unpredictable nature of team-sport. The repeated-sprint protocol was adopted from a study by Brade et al. (2013). The exercises were performed on a calibrated front access cycle ergometer (Model EX-10, Repco, Victoria, Australia). During exercise, participants ingested 100 ml of tap water (room temperature) every 10 min to offset sweat losses. The S7 test was performed again after 27 min of exercise whilst cycling, while the OSPAN was performed again after completing the exercise. Throughout the exercise, thermal sensation (TS; 0 = unbearably cold to 8 = unbearably hot, Young et al., 1987) was measured every 5 min.

Cognitive tests

The OSPAN task assesses working memory capacity (Turner and Engle, 1989). This test is a computerised cognitive test administered using Inquisit 5 software (Millisecond Software, USA) and requires participants to remember correctly the serial order of presented letters and simultaneously answer math problems as a secondary task distractor (e.g., (8 / 4 + 3 = ?) as rapidly as possible. This test takes ~10 min to complete. There were 15 sets of trials in total where each set size ranged from 3-7 letters and included varied math problems. In total, there were 75 letters to be remembered and 75 math problems to be solved, with the presentation of these variables randomly programmed by the software for each session. The outcome measure was the sum of the total number of correct answers, with a total mark of 75 (Bayliss et al., 2003). The task's internal consistency is α = 0.78, while test-retest reliability coefficients have been recorded to be 0.83 (Unsworth et al., 2005). This task has been previously used to assess cognitive performance during exercise in the heat (Mazalan et al., 2021).

The S7 test assesses attention and working memory (Bristow et al., 2016). Participants were required to count down out loud from any random number given (between 900 to 1000) by sevens in 1 min (similar to Hayman, 1942). Any mistake in calculations were carried on by subtracting from the current number given. The outcomes measured were the total number of correct and incorrect answers. The test was administered verbally at three-time points during exercise (prior to precooling, after precooling and 3 min before the end of exercise).

Statistical analyses

All statistical data were analysed using the IBM Statistical Package for Social Sciences version 28.0 (SPSS Inc, Chicago, IL, USA); descriptive statistics were presented as mean ± standard deviation unless otherwise stated. Data was assessed for normality (Shapiro-Wilk test) and sphericity (Mauchly's test). Two-way, repeated-measures ANOVAs were performed on the data to test for condition differences. Statistical significance was set at $p \leq 0.05$. Where main interaction effects occurred, post hoc comparisons (Bonferroni) were conducted and paired sample *t*-tests were used to identify specific condition differences if significance was found. In addition, Cohen's *d* effect sizes (ES) were used to identify meaningful differences in the data (Cohen, 1988) with only moderate (0.5-0.8) and large (>0.8) ES reported. All values are expressed as mean ± SD.

Results

There were no differences in environmental conditions (p > 0.05; 34.9 ± 0.9° C, 70.1 ± 6.8 % RH) or the amount of total work done (CON: 108540 ± 19747 Joule [J], ICE: 110654 ± 20895 J, p > 0.05) between trials.

Serial seven scores significantly declined over time in CON compared to baseline (-3, p = 0.01, *d* = 1.5, 0.36 to 2.43 95% CI) but were maintained in ICE (0, p = 0.08). Further, moderate to large ES demonstrated an increase in scores in ICE between baseline and prior to exercise (*d* = 0.8, -0.19 to 1.73 95% CI), and a decline in scores after 27 min of exercise compared to prior to exercise (*d* = 0.69, -0.31 to 1.59 95% CI). However, S7 scores in ICE were not different between baseline and 27 min into exercise, suggesting that cognitive performance on this task was maintained over the exercise protocol (p > 0.05). At min 27, the average S7 score in CON was significantly lower than ICE (p = 0.01, *d* = 1.30, 0.19 to 2.20 95% CI; Table 5.1).

Similarly, OSPAN scores followed the same pattern as S7 scores. Baseline OSPAN scores were similar in both CON and ICE (65.1 ± 5.5, 65.0 ± 5.4, p > 0.05 respectively). Whilst scores in CON significantly declined over time (p = 0.03, *d* = 0.9, -0.08 to 1.74 95% CI), scores in ICE were observed to be maintained between baseline (65.0 ± 5.4) and min 30 (66.8 ± 4.2, p = 0.09). Further, scores for OSPAN were significantly lower in CON compared to ICE at the end of the exercise (p = 0.003, *d* = 0.78, 0.23 to 1.68 95% CI; Table 1).

Table 1. Mean (± SD), Serial seven (S7) and OSPAN total correct scores across no-cooling (CON) and cooling (ICE) trials when exercising in the heat (*n* = 9).

Time	Time	CON	ICE
Serial Seven	Baseline	19.2 ± 2	20 ± 2.6[a]
	Prior to exercise	17.6 ± 2.2	22.3 ± 2.9 [a]
	Min 27	16.1 ± 2.1#	20 ± 3.7*⁋
OSPAN	Baseline	65.1 ± 5.5	65 ± 5.4
	Min 30	63.1 ± 5.2#	66.8 ± 4.2*

# indicates a significant difference from baseline (p < 0.05). * indicates a significant difference from CON (p < 0.05). ⁋ indicates moderate to large effect sizes compared with CON (*d* = 0.5 - 0.8). [a] indicates a moderate to large effect size compared to scores recorded prior to exercise.

Similar T_c values were observed at baseline for ICE and CON (37.00 ± 0.26°C, 36.93 ± 0.25°C, respectively, p > 0.05). Precooling led to a significant reduction in T_c as early as min 5 (ICE: 36.91 ± 0.25°C) into the ice ingestion compared to baseline (37 ± 0.26°C, p < 0.001, *d* = 0.35, -1.26 to 0.6 95% CI), with T_c further declining over the 30 min period of precooling (-0.67°C). At the end of precooling, T_c was significantly lower in ICE compared to CON (ICE: 36.33 ± 0.31°C, CON: 37.10 ± 0.11°C, p < 0.001, *d* = 3.31, 1.69 to 4.41 95% CI). Further, T_c remained significantly lower in ICE compared to CON at the end of exercise protocol (ICE: 38.07 ± 0.37°C; CON: 38.5 ± 0.22°C, p = 0.03, *d* = 1.41, 0.44 to 2.31 95% CI; Figure 1a).

Forehead temperature was similar at baseline between trials (CON: 35.39 ± 0.39°C, ICE: 35.52 ± 0.38°C, p = 0.86). ICE significantly reduced T_h following precooling (min 30) compared to baseline (-0.59°C, p < 0.001, *d* = 1.53, 0.24 to 2.26 95% CI), with T_h commencing to decline at the 15^{th} min mark of the cooling protocol (ICE: 35.22 ± 0.42°C, CON: 35.68 ± 0.32°C, p = 0.02, *d* = 1.23, -0.14 to 2.13 95% CI) compared to CON. Meanwhile, T_h significantly increased in CON (min 30) compared to baseline (+0.54°C, p < 0.01, *d* = 1.53, 0.38 to 2.45 95% CI) during the cooling/no-cooling protocol. Furthermore, T_h was significantly lower at the start of the exercise in ICE compared to CON (min 0: -0.5°C, p = 0.004, *d* = 2.09, 0.81 to 3.04 95% CI), but was not different to CON from min 5 onwards into the exercise. Moderate to large ES suggested a tendency for T_h to be lower for ICE compared to CON at every 5 min interval of the exercise protocol (p = 0.06 - 0.25, *d* = 0.66 - 1.09; Figure 1b).

Additionally, TS was significantly lower in ICE compared to CON at the beginning of exercise (min 0), and following precooling (p = 0.008, *d* = 1.57, 0.41 to 2.49 95% CI%; Table 2). While there was no main effect for trial (p = 0.78), mean TS increased progressively across the protocol, with this supported by main effect for time (p < 0.001), as well as large ES compared to baseline in both trials (CON: *d* = 7.7, 4.59 to 9.56 95% CI; ICE: *d* = 9.8, 5.95 to 12.15 95% CI).

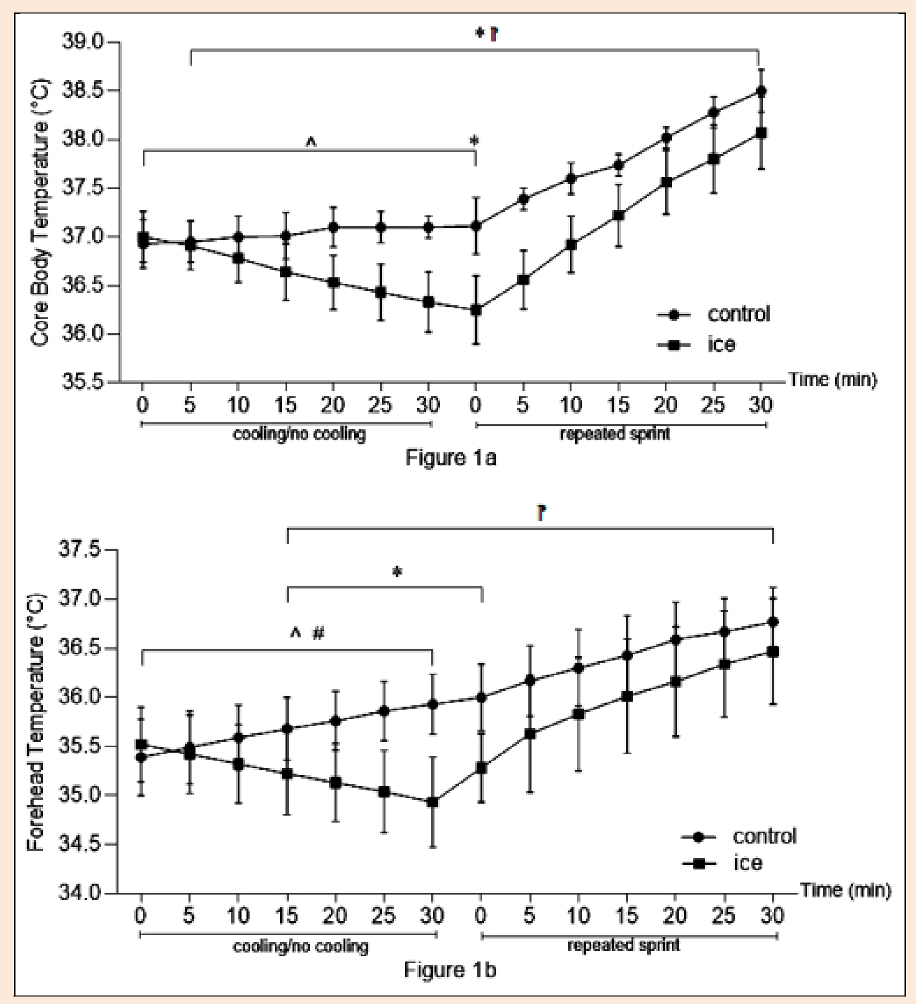

Figure 1. Mean (± SD) core body temperature throughout the precooling period and repeated sprint (*n*=9); b. Mean (± SD) forehead temperature throughout the precooling period and repeated sprint (*n*=9). CON: control, ICE: crushed ice ingestion. ^ indicates a significant difference compared with baseline for ICE ($p < 0.05$). # indicates a significant difference compared with baseline for CON ($p < 0.05$). * indicates a significant difference of ICE compared with CON ($p < 0.05$). ⁋ indicates moderate to large effect sizes of ICE compared with CON ($d = 0.5 - 0.8$).

Table 2. Mean (± SD), thermal sensation across trials when exercising in the heat ($n = 9$). CON: control, ICE: crushed ice ingestion.

Time (min)	CON	ICE
0	4.5 ± 0.3	4.1 ± 0.2*⁋
5	4.9 ± 0.4	4.4 ± 0.2
10	5.4 ± 0.4	5.0 ± 0.3
15	5.8 ± 0.4	5.4 ±0.3
20	6.2 ± 0.3	5.8 ± 0.4
25	6.6 ± 0.2	6.1 ± 0.3
30	6.8 ± 0.3^	6.6 ± 0.3#

* indicates a significant difference of ICE compared to CON ($p < 0.05$). # indicates a large effect size compared with baseline ($d > .08$). ⁋ indicates a large effect size compared with CON ($d > .08$).

Discussion

This study examined the effect of crushed ice ingestion prior to exercise in hot, humid conditions on cognitive performance assessed prior to, during and after a repeated-sprint exercise. Results found that ice ingestion (7 $g \cdot kg^{-1}$) maintained working memory performance over the course of the protocol, as measured by S7 and OSPAN tests, with cognitive function declining in the control condition. Further, ice ingestion reduced T_c, T_h and TS prior to exercise, with T_c remaining significantly lower throughout exercise compared to the control trial.

The current findings suggest that precooling via ice ingestion blunted the effect of heat on working memory, with similar scores found for cognitive performance between baseline and min 27 (S7) and min 30 (OSPAN) of exercise. It is noteworthy that when participants completed the final cognitive tests towards the end of exercise, T_c in CON was peaking at ~38.5°C, the stipulated threshold for cognitive deficits on some tasks (Hocking et al., 2001). Meanwhile in ICE, the highest T_c recorded during exercise was ~38.1°C. This may explain the preservation of cognitive performance in this trial, observed by constant test scores over the course of the protocol, despite exposure to heat and exercise. These results suggest that a T_c of ~38.1°C does not disturb cognitive function in respect to OSPAN and S7 performance. These findings are in agreement with previous studies, suggesting that cooling initially facilitates the preservation of cognitive performance by way of inducement and maintenance of a lower T_c (Racinais et al., 2008, Saldaris et al. 2020).

Saldaris et al. (2020) reported an improvement in working memory following crushed ice ingestion (7 g·kg^{-1}) during and after 90 min of endurance exercise in the heat, compared to no-cooling, despite T_c peaking at ~38.7°C in both trials. Saldaris et al. (2020) also noted that T_c, TS and T_h were significantly lower after ice ingestion, compared to no-cooling, with T_h staying significantly lower 15 min into exercise. These researchers suggested that the reduction in T_c, T_h, and TS, as a result of ice ingestion, may have allowed the athlete to focus more on the task in hand rather than the discomfort of the heat (Saldaris et al., 2020). In the current study, a reduction was observed in T_c (-0.67°C), T_h (-0.59°C) and TS following ice ingestion, with associated cognitive benefits apparent. It is possible that a reduction in the combination of these variables, rather than T_c alone, may result in the maintenance of subsequent cognitive performance during exercise in the heat.

In regards to cooling methods, these can be classified as being either internal (the ingestion of crushed ice) or external (the wearing of cooling vests/ice packs/head cooling cap) strategies that cool the body either pre (prior), per (mid), or post-exercise (Best et al., 2018; Lee et al., 2014; Gaoua et al., 2011; Mazalan et al., 2022; Saldaris et al., 2020). In contrast to the results found in the current study in respect to ice ingestion (internal precooling), external precooling using a cooling cap was reported to reduce pre-exercise T_h (-2.1°C) but not T_c prior to 60 min of running at 70% $\dot{V}O_2$peak in the heat (Mazalan et al., 2021). These researchers reported that this cooling effect diminished at the beginning of exercise with no benefit observed for subsequent cognitive performance (Mazalan et al., 2021). Similarly, the combination of external cooling devices (ice jacket and hand cooling gloves) prior to a cycling race simulation in the heat did not reduce T_c during exercise (T_h not assessed) or have a benefit for subsequent cognitive performance (Maroni et al., 2019). Based on these findings, it can be suggested that internal precooling (via ice ingestion) may provide a greater cooling benefit on physiological and cognitive responses compared to external means (cooling devices). In this context, internal precooling may delay the drift in T_c and T_h towards hyperthermia and subsequently act as a heat sink by allowing greater heat transfer via conduction, consequently reducing endogenous heat accumulation during exercise. Notably, ice changing its form from solid to liquid requires a great deal of heat absorption (Merrick et al., 2003). Therefore, an advantage of the internal heat loss that occurs as a result of ice ingestion lies in the efficiency of the heat transfer in the body. Notably, combining internal and external cooling methods has been shown to be more effective at lowering T_c than just utilising one cooling mode. For example, the reduction in T_c observed following cooling was greater in the study by Saldaris et al. (2020) (T_c: -0.80°C) compared to the current study (T_c: -0.67°C), most likely due to the cooling protocol being conducted in a cool room (~20°C) rather than an environmental chamber (~35°C). This suggests that the combination of internal cooling (ice ingestion) and external cooling (exposure to a cool room) prior to exercise could provide a greater heat sink by lowering T_c even further during the cooling protocol. Overall, these findings are of special interest for athletes who play sports where a deterioration in working memory in the heat could affect decision making under pressure whilst playing in an unpredictable game environment, such as team sports (Jiménez-Pavón, et al., 2011). Further, these findings are of relevance to sports event organisers, who may consider establishing a cooling station at events that provide crushed ice to athletes, which can be ingested prior to (or even during) exercise in the heat to preserve athletes' subsequent physiological and cognitive performance.

Assessment of T_h in this and other studies (Saldaris et al., 2019; 2020), represented an indirect assessment of brain temperature, with ice ingestion shown to reduce this variable. As noted earlier, this reduction in T_h, was proposed to be due to conductive cooling resulting from the ingested ice cooling the blood in the carotid arteries, which then flowed to the brain (Onitsuka et al., 2018). This may result in the brain being better able to dissipate heat and hence blunt the exercise heat-induced rise in T_h. In support of this, Onitsuka et al. (2018) reported a lower brain temperature (-0.4°C) associated with ice slushy ingestion (7.5 g·kg^{-1}), as determined by magnetic resonance spectroscopy. The reduction in T_h reported by these researchers over the cooling period was less than that found in the current study (T_h -0.4°C versus T_h -0.57°C), however, the cooling period used by Onitsuka et al. (2018) was shorter (15 min versus 30 min). This suggests that a longer cooling period in the current study facilitated a greater reduction in T_h, which in turn may further benefit cognitive performance. While the use of magnetic resonance spectroscopy represents a better method for assessing brain temperature than measuring forehead temperature, this is not feasible during exercise, as it requires athletes to be in a supine position.

Conclusion

In conclusion, this study demonstrated that precooling with ice ingestion resulted in the maintenance of working memory, compared to no-cooling. This outcome was most likely a result of lower T_c and T_h, and possibly TS that occurred after ice ingestion. This suggests that ice ingestion is an effective method that can reduce thermal strain, subsequently enhancing the brain's ability to function during exposure to heat and exercise. Overall, these results demonstrate an effective and efficient strategy to preserve cognitive performance during exercise in hot and humid conditions.

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Key points

- Thirty minutes of precooling via crushed ice ingestion able to preserve and maintain cognitive efficiency (working memory) during repeated-sprint exercise in the heat compared to no cooling trial.
- The preservation and maintenance in cognitive performance is associated with a reduction in T_h and T_c following crushed ice ingestion prior to repeated-sprint exercise in the heat.
- Crushed ice ingestion significantly reduced TS after cooling but the cooling sensation was observed to diminish during the exercise.

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