Manuscript Title: Mixed-Methods Pre-Match Cooling Improves Simulated Soccer Performance in The Heat.

Running Head: Cooling during simulated soccer

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Abstract: This investigation examined the effects of three pre-match and half-time cooling manoeuvres on physical performance and associated physiological and perceptual responses in eight University soccer players during a non-motorised treadmill based individualised soccer-specific simulation [intermittent soccer performance test (iSPT)] at 30°C. Four randomised experimental trials were completed; following 30-min (pre-match) and 15-min (half-time) cooling manoeuvres via: (1) ice slurry ingestion (SLURRY); (2) ice-packs placed on the quadriceps and hamstrings (PACKS); (3) mixed-methods (MM; PACKS and SLURRY concurrently); or no-cooling (CON). In iSPT first half, a moderate increase in total (Mean ± Standard Deviation: 108 ± 57m, qualitative inference: most likely, Cohen's *d*: 0.87, 90%CL: ±0.31), high-speed (56 ± 46m, very likely, 0.68 ±0.38) and variable run (15 ± 5m, very likely, 0.81 ±0.47) distance covered was reported in MM compared with CON. Additionally, pre-match reductions in thermal sensation (-1.0 ± 0.5, most likely, -0.91 ±0.36), rectal (-0.6 ± 0.1°C, very likely, -0.86 ±0.35) and skin temperature (-1.1 ± 0.3°C, very likely, -0.88 ±0.42) continued throughout iSPT first half. Physical performance during iSPT first half was unaltered in SLURRY and PACKS compared to CON. Rectal temperature was moderately increased in SLURRY at 45-min (0.2 ± 0.1°C, very likely, 0.67 ±0.36). Condition did not influence any measure in iSPT second half compared to CON. Only MM pre-match cooling augmented physical performance during iSPT first half, likely due to peripheral and central thermoregulatory factors favourably influencing first half iSPT performance. Further practical half-time cooling manoeuvres which enhance second half performance are still required.

Keywords: Environmental Physiology, Fatigue, Performance, Team Sport

Introduction

Elite soccer competition can occur within high ambient temperatures exceeding 30^{o}C, as seen during the 2014 Fédération Internationale de Football Association (FIFA) World Cup in Brazil (Nassis, Brito, Dvorak, Chalabi and Racinais, 2015). Soccer match-play performed at 43^{o}C demonstrated a reduction in physical performance (7–26%) and dramatic increases in peak core (T_c: 39.5 ± 0.1^{o}C) and muscle (T_{mu}: 40.3 ± 0.1^{o}C) temperatures (Mohr, Nybo, Grantham and Racinais, 2012). Although variable, high T_c (e.g. >40^{o}C) as seen in other codes of football (Aughey, Goodman and McKenna, 2014) can be associated with the onset of heat illnesses (Armstrong et al., 2007). Whilst augmented T_{mu} improves single sprint performance through enhanced muscle contractility (Racinais and Oksa, 2010), progressive reductions in intermittent and repeated sprint performance/ability (RSA) are observed when T_c exceeds 39°C (Girard, Brocherie and Bishop, 2015). Indeed, elevated T_c (39.2 ± 0.2^{o}C) coincided with reduced sprint performance (-5.8%) in the final 15-min of simulated soccer at 30^{o}C (Aldous et al., 2016); important given a sprint is the most frequently observed movement prior to a goal or assist during soccer match-play (Faude, Koch and Meyer, 2012). Strategies such as cooling manoeuvres [e.g. Ice packs, Ice slurry etc. - (Bongers, Thijssen, Veltmeijer, Hopman and Eijsvogels, 2014)] that can attenuate elevated body temperatures during soccer match-play in the heat are therefore needed relative to performance (Mohr et al., 2012) and player safety (Armstrong et al., 2007) agendas.

Cooling manoeuvres can be applied to the body (external) or ingested (internal), via a singular or combined (mixed-methods) approach pre-match and/or at half-time in soccer (Grantham et al., 2010). Given that T_c exceeding 39^{o}C can decrease RSA (Girard et al., 2015), it is logical that directly pre-cooling the locomotive muscles will create a heat sink that may eventually benefit subsequent RSA in the heat (Castle et al., 2006). This is provided an appropriate warm-up is observed post-pre-cooling (Castle et al., 2006), given that decreased T_{mu} (Lovell, Barrett, Portas and Weston, 2013) may negatively influence initial (i.e. at the start of each half) RSA related performance (Russell et al., 2015a). Practical cooling via ice packs applied to quadriceps and hamstrings reduced both T_c (0.2 ± 0.2°C) and T_{mu} (1.0 ± 2.5°C) prior to a warm up, coinciding with an augmented power output during prolonged intermittent sprint cycling exercise at 33°C (Castle et al., 2006). Ice slurry ingestion causes a pre-exercise decrease in T_c (~0.5°C), attributed to a reduction in body heat storage (Jay and Morris, 2018), which can elicit a similar ergogenic effect on endurance performance at ~34°C compared with impractical pre-exercise cold-water immersion (Siegel, Mate, Watson, Nosaka and Laursen, 2012). However, despite ice slurry ingestion reducing thermal sensation and T_c prior to intermittent sprint performance at 30°C, performance was not favourably altered (Gerrett, Jackson, Yates and Thomas, 2017). Furthermore, evidence regarding combined external and internal mixed-method cooling manoeuvres relative to RSA in the heat is sparse, despite reductions in body temperatures being potentially augmented compared with their singular use (Bongers et al., 2014).

During soccer match-play, combined pre-match and half-time cooling via ice vests, ice towels and ice slurry ingestion revealed a moderate effect ($4\text{m} \cdot \text{min}^{-1}$, d = 0.6) on total running distance, alongside blunted elevations in T_c and thermal sensation (Duffield, Coutts, McCall and Burgess, 2013). However, soccer match-play is highly variable (e.g. tactics, environment, etc.) which renders meaningful inferences from interventions upon key physical performance measures (e.g. high-speed running), challenging without a practically unrealistic sample size [e.g. 80 players (Gregson, Drust, Atkinson and Di Salvo, 2010)]. One solution for quantifying the efficacy of a cooling strategy relative to soccer performance is to utilise an appropriate soccer-specific simulation rather than match-play (Aldous et al., 2016). To date only three such studies have been conducted, however the omission of a warm up post-pre-cooling (Price, Boyd and Goosey-Tolfrey, 2009), any relevant performance measures (Clarke, Maclaren, Reilly and Drust, 2011) and the use of non-practical pre-cooling interventions such as prolonged cold-water showering (Drust, Cable and Reilly, 2000) are impractical to soccer. Additionally, their utilised simulations did not include the recommended individualised and externally cued speed thresholds to enable appropriate quantification of the efficacy of their cooling manoeuvres (Taylor and Rollo, 2014). The intermittent Soccer Performance Test (iSPT) adheres to these recommendations and is a valid, reliable and individualised soccer simulation (Aldous et al., 2014) that has successfully identified changes in simulated soccer performance in hot environments (Aldous et al., 2016). Thus, iSPT would provide an appropriate tool to determine the effects of pre-match and half-time cooling on simulated soccer.

The aim of this study was to investigate the efficacy of pre-match and half-time cooling strategies: (1) external (ice packs placed on the quadriceps and hamstrings; PACKS); (2) internal (ice slurry ingestion; SLURRY); and (3) mixed-methods (PACKS and SLURRY procedures combined; MM) on simulated soccer performance at 30°C. It was hypothesized that all cooling strategies would augment physical performance throughout iSPT compared to control (no cooling).

Methods

Participants

Eight male, University-level soccer players [mean ± SD; 22 ± 3y; 76 ± 11kg; 187 ± 20cm; $\dot{V}O_{2max}$ = 56 ± 9mL·kg^{-1}·min^{-1}] volunteered for this study which was approved by the University of

Bedfordshire Ethics Committee and conformed to the Declaration of Helsinki. Participants trained $\geq$2 times and played at least one full 90-min match in the British Universities and Colleges Sport Midlands 2B Division per week. Based on an *a priori* power calculation (using Aldous et al. 2016; G*Power 3); a minimum of 8 participants were required to achieve 99% power, at $P<0.05$ and $d = 0.5$ for a change in high-speed distance covered.

General Experimental Controls

In the 24 h prior to experimental trials, participants standardised their food and water consumption (food diary), and consumed 2-3 L of water, in-line with their normal drinking habits. Alcohol, cigarettes, caffeine and strenuous exercise were abstained from for >48 h prior to testing. Participants refrained from ergogenic aids supplementation throughout the study and had not been exposed to >30^{o}C for three months prior to this study. All familiarisation (FAM), peak speed assessments (PSA) and iSPTs were completed on the same calibrated non-motorised treadmill (NMT: Force 3.0, Woodway, Cranlea, Birmingham). Participants were secured onto the NMT using a tether belt and harness attached around the waist. The harness was attached to the NMT at an angle of 8^{o} from horizontal (Aldous et al., 2014, 2016). Hydration status was assessed via urine osmolality (Atago-Vitech-Scientific, Pocket-PAL-OSMO, HaB-Direct, Southam) with euhydration accepted at <600 mOsm·L^{-1} (Hillman et al., 2013).

Experimental Design

Three FAM and two PSA sessions (visits 1-3) were sufficient to minimise learning effects and produce valid and reliable [Intraclass Correlation = 0.80-0.98] physical performance and associated physiological and perceptual responses data (Aldous et al., 2014). In a randomized and counterbalanced repeated measures design, iSPT was completed on four occasions; (1) SLURRY; (2) PACKS; (3) MM: PACKS and SLURRY concurrently; or CON. All experimental trials were completed within a controlled laboratory environmental chamber (Flower-House, Farm-House, Two-Wests and Elliot, Chesterfield) at an air temperature of 30.7 ± 0.3°C and relative humidity of 50.9 ± 4.2% and administered using a portable heater (Bio-Green, Arkansas-3000, Hampshire). All trials comprised of the following time periods: 30-min pre-match (cooling or no cooling), 10-min warm up at 30°C on the NMT at a speed of 8 $km \cdot hr^{-1}$, including two brief 4 s sprints, a 10-min rest period, 45-min iSPT first half, 15-min half-time (cooling or no cooling) and 45-min iSPT second half.

<u>*The intermittent Soccer Performance Test (iSPT):*</u> The iSPT consists of two 45-min halves comprised of three identical 15-min intermittent exercise blocks (Aldous et al., 2014, 2016). Throughout each exercise block, for all target speeds (apart from the variable run) participants interacted with a computer program (Innervation, Pacer Performance System Software, Lismore, Australia) by matching a red line on the screen (target speed) with their current (actual) speed (green line). Participants were instructed to match their current speed with the target speed as closely as possible throughout iSPT, apart from the variable run. Audio cues specific to each movement category (e.g. run) were also presented by three audible tones, followed by an audible command (e.g., "beep", "beep", "beep", "run"). Finally, four self-selected high-speed 'variable runs' were completed at 13-14-min of each 15-min block. During the variable run, participants were instructed to cover as much distance as possible without sprinting. A sprint was defined as the peak sprint speed (PSS) achieved in the PSA, with no incidences of sprinting observed during the variable run. The variable run was executed at 82 ± 5% (range: 68-89%) of the defined PSS across all experimental trials. The variable run has been shown reliable to quantify the distance

covered by a participant above the second ventilatory threshold, at a self-selected running speed without an external cue (Aldous et al., 2014).

Cooling Manoeuvres: All cooling manoeuvres were completed with participants seated in a temperate environment (18.0 ± 0.9ºC; 50.3 ± 4.7% rH). Room temperature water (21.0 ± 0.6ºC) was consumed during CON and PACKS, divided into three portions to be ingested every 10-min (pre-match) and 5-min (half-time). The volume of room temperature water drunk was relative to the individualised melted liquid volume in SLURRY. In MM, SLURRY and PACKS methodologies were performed simultaneously.

SLURRY: Participants ingested 7.5 $g \cdot kg^{-1}$ body mass of ice slurry (−1°C) pre-match (volume: 500-800mL) and 3.75 $g \cdot kg^{-1}$ at half-time (volume: 250-400 mL). On each occasion, the ice slurry was divided into three equal portions ingested every 10-min (pre-match) and 5-min (half-time) ensuring even ingestion throughout the cooling phase. The drink consisted of two-thirds shaved ice, using a snow cone maker (Snow Cone Maker, JM Posner, Amazon Ltd, Alton) and one-third sugar free diluted drinking cordial (Tesco, UK).

PACKS: Ice packs (Aeroplast, hot/cold pack, Hertfordshire Suppliers, Hertfordshire) were removed from a freezer (freezer temperature: -20ºC) with a surface temperature of -14.0 ± 4.6ºC and wrapped in a cotton cloth (Compression Cuff Holder, Lewis-Plast, Lewis Medical Supplies, Stockport) to avoid damage to the skin. Ice packs were placed on the anterior, lateral and posterior aspects of the quadriceps and hamstring muscle groups. Ice packs were replaced every 15-min (pre-match), as pilot data indicated that the packs were nearly melted by this time.

Physical performance measures: Total distance covered (TD) comprised all movement categories [categories as a percentage of PSS were: walk (20%), jog (35%), run (50%), fast run (65%), variable run (unset) and sprint (100%)] and was calculated across both halves. Data for high-speed distance (HSD) covered was derived from fast run, variable run (VRD) and sprint (SD) distances covered, while low-speed distance (LSD) covered, included walk, jog and run distances covered (Aldous et al., 2014). For each half, LSD, HSD, VRD and SD covered were computed with performance changes calculated in distance covered (m) between halves (Aldous et al., 2014).

Physiological Measurements: Prior to FAM, height (cm) was measured using a Holtain Stationmaster (Stadiometer, Harpenden, HAR 98.602, Holtain). To quantify fluid loss, participant nude dried body mass change was measured pre- and post-iSPT using digital scales (Tanita, BWB0800, Allied Weighing). Heart rate [HR – Coefficient of variation (CV): 1.8%] was recorded beat-by-beat using a telemetric HR monitor (Polar, FS1, Polar Electro, Oy) using a 1-min mean approach within analyses. A single-use rectal thermistor (Henleys, 400H, Henleys Medical, Welwyn Garden City) was used to measure rectal temperature (T_{re} - CV: 0.4%) from a depth of 10 cm past the anal sphincter and read by a connected data logger (Measurement, 4600, Henley-medical, Welwyn Garden City). Skin thermistors (Grant, EUS-U-VS5-0, Wessex-Power, Dorset) were attached to the right side of the body at the centre of the pectoralis major, biceps brachi, rectus femoris, and gastrocnemius to measure skin temperature (T_{sk} - CV: 2.0%) as per the Ramanathan (1964) equation; with this data recorded by a data logger (Eltek/Squirrel, Squirrel Series/model 451, Wessex Power, Dorset). All T_{re} and T_{sk}, perceived exertion [CV: 3.3% - RPE: Borg 6-20 scale - (Borg, 1998)] and thermal sensation [CV: 4.5% - TS: 0-8 scale - (Young, Sawka, Epstein, Decristofano and Pandolf, 1987)] measures were collected at 15-min intervals across the experimental data collection period.

Statistical Analysis

All data in tables, text and figures are presented as mean ± SD with 90% confidence limits/intervals (90% CL/CI) and were analysed using the contemporary magnitude based inferences qualitative approach (Hopkins, Marshall, Batterham and Hanin, 2009). Using a customised spreadsheet (Hopkins, 2003), all data were first log transformed to reduce bias arising from non-uniformity of error and then back-transformed. Comparisons between pre-match cooling strategies throughout iSPT were standardised using Cohen's *d* effect sizes with qualitative interpretations [0.00-0.19, trivial; 0.20-0.59, small; 0.60-1.19, moderate; >1.20, large (Hopkins et al., 2009)]. The differences with uncertainty of the estimates are shown as 90% CL. If the 90% CI overlapped positive and negative trivial ES values, the effect was deemed unclear. As per best practice for team-sport specific measures, the smallest worthwhile change for all physical performance measures was estimated by using 0.2 × between-subject SD (Hopkins et al., 2009). The smallest worthwhile change for all physiological and perceptual responses was taken from a previous meta-analysis (Choo, Nosaka, Peiffer, Ihsan and Abbiss, 2018). Qualitative chances of measurements affecting performance were assessed qualitatively as follows: <1%, most unlikely; 1-5%, very unlikely; 5-25%, unlikely; 25−75%, possible; 75−95%, likely; 95−99%; very likely; >99%, almost certain (Hopkins et al., 2009).

Results **Table 1, Figure 1, 2 and 3 near here**

Physical performance: In CON, a moderate decrease for all physical performance measures was evident in iSPT second half compared with the first half, which was not influenced by condition. In PACKS and SLURRY, physical performance was unaltered compared with CON throughout both halves of iSPT. There was a moderate increase in TD (most likely, 0.87 ±0.31), HSD (very likely, 0.68 ±0.38) and VRD (very likely, 0.81 ±0.47) covered in the first half of MM, compared with CON. There was an unclear improvement to physical performance in PACKS and SLURRY compared with CON, however, no changes were evident to TD, HSD and VRD covered in the second half between all conditions (Figure 1, 2 and 3). No changes in LSD and SD covered were evident throughout iSPT.

Body Temperatures, Physiological and Perceptual Measures: A large increase in T_{re}, T_{sk}, RPE and TS were seen throughout iSPT first half at 30-min and 45-min compared with 0-min. In iSPT second half, at 90-min and 105-min a large increase in T_{re}, T_{sk}, RPE and TS were evident compared with 60-min (start of the second half) in CON. However, RPE, HR and body mass changes were unaltered between all conditions throughout iSPT. In PACKS, a moderate reduction in T_{sk} (very likely, -0.88 ±0.47) and TS (very likely, -0.63 ±0.27) post cooling was evident compared with CON. In PACKS, throughout iSPT T_{re}, T_{sk} and TS were all unchanged compared with CON. Pre-match cooling revealed a moderate reduction in T_{re} (very likely, -0.66 ±0.24) and TS (very likely, -0.63 ±0.26) in SLURRY compared with CON. No differences in TS and T_{sk} arose, however, a moderate elevation in T_{re} was evident at 45 min (very likely, 0.67 ±0.36) in SLURRY compared with CON. In MM, there was a moderate reduction in both rectal temperature, (very likely, -0.86 ±0.35), skin temperature (very likely, -0.88 ±0.42) and TS (very likely, -0.91 ±0.36) pre-match which continued throughout the first half of iSPT compared with CON. No differences in T_{re}, T_{sk} and TS were observed between all conditions in the second half (Table 1, Figure 2 and 3).

Discussion

The major findings of the present study are that 30-min of MM pre-match cooling revealed a moderate increase in physical performance and a moderate reduction in T_{re}, T_{sk} and TS in iSPT first half. The 30-min of pre-match cooling in PACKS and SLURRY reduced TS, T_{re} and T_{sk} without changes in physical performance during iSPT first half, whilst T_{re} moderately increased in SLURRY at 45-min compared to CON. Finally, half-time cooling strategies revealed no effect upon physical performance in iSPT second half.

<u>Pre-iSPT cooling</u>

Pre-match cooling in MM was the most effective strategy, with favourable reductions in T_{re}, T_{sk} and TS pre-match and across iSPT first half compared with CON. This coincided with a clear moderate increase in TD, HSD and VRD covered during iSPT first half in MM compared to CON. Utilising soccer match-play designs to examine the efficacy of a cooling intervention can be problematic due to a plethora of match-factors [e.g. score line, tactics, etc. (Gregson et al., 2010)] and the adaptive pacing strategies employed (Aldous et al., 2016). The iSPT minimises the presence of both match factors and pacing strategies, due to the same exercise being performed in each half, facilitated by the individualised and externally cued speed thresholds employed (Aldous et al., 2014). These contribute to a reduction in variation for key physical performance measures [HSD – CV: 1.5% (Aldous et al., 2014)] compared with match-play data [HSD – CV: 17.1% (Gregson et al., 2010)]. Therefore, the efficacy of pre-match cooling was established within the present study, without both adaptive pacing strategies (Aldous et al., 2016) and a plethora of confounding match factors occurring (Gregson et al., 2010).

The elevation in VRD covered during iSPT first half in MM compared to CON suggests participants chose a faster self-selected running speed in MM. This may be due to a strong sensory effect, as the present data revealed a moderate decrease in TS during the first half in MM compared to CON. Indeed, reductions in T_{sk} and TS can on occasions be beneficial to an athlete, without changes in T_{re}, HR or RPE (Stevens, Mauger, Hassmen and Taylor, 2018). Menthol mouth rinse cooling, in the absence of T_{re} changes, has been shown to improve endurance performance (Stevens et al., 2016b) via the activation of thermoreceptors in the mouth, which was reported to favourably influence the interpretation of tissue temperature by higher centres (Stevens, Taylor and Dascombe, 2016a). However, ice slurry ingestion has recently be shown to directly reduce brain temperature (Onitsuka et al., 2018). Therefore, it is likely that the ice slurry ingestion activated the thermoreceptors located in the mouth [i.e. perceptual effect (Stevens et al., 2018)] and perhaps directly reduced brain temperature (Onitsuka et al., 2018), while the ice packs reduced T_{sk} (and perhaps T_{mu}) of the quadriceps dampening TS and eliciting an ergogenic effect on VRD and HSD covered in MM during the first half of iSPT. However, pre-cooling with ice on the locomotive muscles should be used cautiously as an uncontrolled reduction in T_{mu} can decrease subsequent exercise performance by diminishing muscle contractility (Gray, De Vito, Nimmo, Farina and Ferguson, 2006). Thus, to help offset the drop in T_{mu} and prevent exercise performance decline early in the first half, ice pack pre-cooling should be followed by an appropriate warm-up after cooling, prior to match-play (Russell et al., 2015a).

In PACKS, a moderate reduction in T_{sk} and TS pre-iSPT was seen alongside a trivial change in T_{re} (-0.1°C) throughout iSPT first half. This coincided with no improvement to physical performance in PACKS compared with CON, likely from the volume (Minett, Duffield, Marino and Portus, 2011) and/or duration (Minett, Duffield, Marino and Portus, 2012) of the ice packs pre-cooling being inadequate to reduce T_{re} by the sufficient magnitude (~0.2°C) to improve heat storage capacity and oxygen delivery to the working muscles (Girard et al., 2015). Pre-exercise ice slurry ingestion reduced T_{re} in SLURRY, but an undesirable, moderate increase in T_{re} still occurred during iSPT first half compared with CON. The elevation in T_{re} is likely from pre-exercise ice slurry ingestion delaying both sweating and vasodilatory responses (Jay and Morris, 2018), thus increasing heat storage during the first half. Similarly, pre-exercise ice slurry ingestion prior to prolonged RSA (Gerrett et al., 2017) revealed no improvement in physical performance despite pre-exercise reductions in T_c. In MM, PACKS and SLURRY were used simultaneously, resulting in peripheral (T_{sk}) and central (T_{re}) thermoregulatory factors being reduced pre-exercise and throughout the first half compared with CON. Therefore, heat transfer and central drive were likely increased in MM, facilitating a reduction in various tissue temperatures (Castle et al., 2006; Onitsuka et al., 2018) and their favourable interpretation by higher centres (Stevens et al., 2018).

Half-time iSPT cooling

Half-time cooling strategies had no effect on physical performance, physiological and perceptual measures at half-time nor throughout iSPT second half. The data contradicts Minett et al. (2011) who used 5-min of whole body mixed method external cooling (ice packs, towels and vest) between halves, which significantly improved TD covered by 5% during the second half of a self-paced intermittent sprint exercise protocol at 33^{o}C. The 5-min duration of half time cooling is highly practical (Minett et al., 2011), unlike the 15-min duration used within the present experimental design, since, soccer practitioners only have 2-6-min available to implement interventions at half-time (Russell, West, Harper, Cook and Kilduff, 2015b). Therefore, future half-time cooling strategies should be more aggressive compared with a pre-match cooling strategy (Minett et al., 2011) and abide by the limited time practitioners have with players during the half-time interval (Russell et al., 2015b) while incorporating an appropriate re-warm-up (Lovell et al., 2013). An appropriate re-warm-up (Lovell et al., 2013) is important to offset reduced T_{mu}

medicated performance decrements (Russell et al., 2015b), a potential risk of aggressive 5-min half-time cooling.

Practical Applications

The data from this study reveals that 30-min of mixed method pre-match cooling can augment simulated soccer performance in 30^{o}C, albeit only within iSPT first half. Dramatic elevations (>39^{o}C within ~20-45-min) in T_c are seen during simulated (Coull et al., 2015; Aldous et al., 2016) and match-play (Mohr et al., 2012) soccer performed in the heat (30-43^{o}C). As discussed, elevated T_c (>39^{o}C) is considered a primary factor to progressive reductions to RSA (Girard et al., 2015). The T_{re} values seen in CON (>39^{o}C) exceeded this threshold within a similar high ambient temperature likely to occur at the upcoming 2022 FIFA World Cup (Qatar). There are currently no governing body restrictions upon the use of pre-match and/or half-time cooling prior to soccer performance. Therefore, these findings may be of interest to practitioners from soccer teams that are competing in a hot environment, when acclimation or acclimatisation is not possible and/or for players that have a history of exertional heat illness given their increased susceptibility (Nichols, 2014). Furthermore, both ice slurry ingestion and ice packs are simple to use, easily portable and inexpensive, so could be considered by players and practitioners prior to training sessions and match-play in the heat. However, as detailed in the present study, both methods should only be used simultaneously, as their singular use is ineffective. The application of ice to active muscle groups (e.g. quadriceps and hamstrings) pre-exercise should also be followed by an appropriate warm-up post-pre-cooling, prior to match-play (Russell et al., 2015a). This is important as perturbations in T_{mu} may potentially decrease RSA at the start of the first half during match-play from diminished muscle contractility (Gray et al., 2006). An increase in high-speed running during the first half was seen in MM and consequently, a coach could take advantage of this elevated exercise intensity by orchestrating a team to play at a higher intensity during the first half (e.g. play a higher pressing match). However, playing style is likely influenced by a myriad of factors [e.g. environmental, tactics etc. (Gregson et al., 2010)] and caution should be taken to ensure soccer players do not select a pace that is too fast within the first half, exacerbating heat-induced decrements in the second half.

Conclusions

In conclusion, only 30-min of mixed-methods pre-match cooling (ice slurry ingestion and ice packs) improved simulated soccer performance at 30^{o}C. However, the elevation in physical performance was only present within iSPT first half and likely due to a decrease in tissue temperatures and TS. No half-time cooling strategy when combined with pre-match cooling improved simulated soccer performance in the heat. Therefore, future research should attempt to apply the pre-match cooling findings from this study in a match-play setting, whereas, laboratory-based research should identify aggressive half-time cooling strategies (compatible with the 2-6-min practitioners have access to players at half-time) to augment second half performance.

Declarations/Acknowledgements

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Figure 1: The standardized differences in the change (90% confidence intervals) in TD (A), HSD (B) and VRD (C) covered during the first and second half of iSPT for CON, PACKS, SLURRY and MM. [a]Most likely moderate ES between CON and MM ($d > 0.6$); [b]Very likely moderate ES between CON and MM.

Figure 2: The mean and SD for TD (A), HSD (B) VRD (C) covered during the first and second half of iSPT for CON, PACKS, SLURRY and MM. The change in T_{re} (D), T_{sk} (E) and TS (F) during the pre-match cooling, warm up (WU), first half (0-45 min), half-time cooling (45-60 min) and second half (60-105 min) of iSPT for CON, PACKS, SLURRY and MM conditions. [a]Most likely moderate ES between CON and MM ($d > 0.6$); [b]Very likely moderate ES between CON and MM. [c]Very likely moderate ES between CON and SLURRY ($d > 0.6$). [d]Very likely moderate ES between CON and PACKS ($d > 0.6$). [e]Very likely moderate ES between the first and second half. [f]Very likely large ES increase compared with 0 min in all conditions. [g]Very likely large ES increase compared with 60 min in all conditions.

Figure 3: Individual responses for TD (A), HSD (B), VRD (C) covered during the first and second half of iSPT. for CON, PACKS, SLURRY and MM. Individual responses for T_{re} (A), T_{sk} (B) and TS (C) during iSPT for CON, PACKS, SLURRY and MM conditions.