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Implementation of a mixed-methods heat acclimation programme in a professional soccer referee before the 2022 FIFA world cup in Qatar: a case study

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ABSTRACT

Objectives This case study reports the real-world practicalities of implementing a mixed-methods heat acclimation (HA) programme before the 2022 FIFA World Cup.

Methods One male English soccer referee (age: 44 years; height: 1.82 m; body mass: 76.0 kg) who had officiated professionally for over 17 years and had over 10 years' experience officiating in European and international matches undertook an 11-session HA programme over 22 days. On days 1 and 22, a 30 min fixed-intensity heat tolerance test (9 km.h^{-1}, 2% gradient, 40°C, 40% relative humidity) was performed, and physiological and perceptual responses were measured. A mixed-methods HA approach was used, including environmental chamber isothermic training, post-temperate training saunas and hot water immersion.

Results Compared with the pre-test, peak core temperature reduced by 0.40°C (38.4 vs 38.0°C; minimal detectable change (MDC) = 0.34°C), peak skin temperature reduced by 0.5°C (36.7 vs 36.2°C; MDC=0.28°C) and peak heart rate reduced by 5 b·min^{-1} (167 vs. 162 b·min^{-1}; MDC=4 b·min^{-1}) in the post-test. In the post-test, the sweat rate increased by 17% (1.94 vs 2.27 L.h^{-1}; MDC=0.42 L.h^{-1}). Peak thermal sensation (7 = 'hot') and the rating of perceived exertion (3 = 'moderate') were unchanged between the tests. However, peak thermal comfort (3 = 'slightly uncomfortable' vs 2 = 'uncomfortable') was rated lower in the post-test.

Conclusion The HA programme elicited positive physiological but indifferent perceptual responses, highlighting that mixed-methods HA can be implemented when a referee still has officiating, travel and training responsibilities during the HA window.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Heat acclimation (HA) programmes are used to attenuate the reduction in performance when competing in hot and humid conditions. These programmes typically last 7–14 days and require athletes to physically train in an environmental chamber under hot and/or humid conditions.

WHAT THIS STUDY ADDS

⇒ The novel aspect of this case study is the presentation of the real-world practicalities of implementing a mixed-methods HA programme concurrently alongside the in-season schedule of a professional referee.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ In practice, athletes with a busy travel, training and/or competition schedule can implement a mixed-methods HA programme with the confidence that it will provide beneficial physiological adaptations.

INTRODUCTION

Major sporting events (eg, FIFA World Cup, Olympic Games and World Championships) are often held in locations where the environmental conditions may negatively impact the performance and health of those performing, including referees.[1] Despite moving the 2022 FIFA World Cup to winter, air temperatures in Qatar's host location were expected to be 25–35°C with ~60% relative humidity. These environmental conditions require specific heat preparation to alleviate the negative consequences.[1–3]

Drust *et al*[4] demonstrated that maximal sprint cycling performance (5×15 s) following 40 min of standardised intermittent cycling was reduced when performed in the heat (40°C) compared with a control (20°C) condition. In addition, Nassis *et al*[5] highlighted that the mean (SD) number of sprints in the 2014 FIFA World Cup was reduced during matches where the environmental stress was high (0.36 (0.04) sprints.minute.player^{-1}) compared with moderate (0.40 (0.05) sprints.minute.player^{-1}) and low (0.41 (0.04) sprints.minute.player^{-1}) environmental stress matches. In addition to impairing physical outputs, heat stress diminishes cognitive function during intermittent sprint performance.[6] Previous research has also shown that at distances greater than 15 m, the accuracy of a referee's decision is reduced.[7] These findings highlight the multifactorial impact of heat stress on referee performance. This is particularly crucial at high-profile international competitions like the FIFA World Cup.

Heat acclimation (HA) is recommended to induce positive physiological and perceptual adaptations to attenuate the potential decline in performance in hot and humid conditions.[1] This can be achieved through active interventions such as performing exercise in hot and humid conditions, eg in an environmental chamber,[8] and passive interventions such as post-exercise heat exposure via a sauna[9] or hot water immersion.[10] Additionally, a combination of active and passive methods can be implemented with this approach, known as mixed-methods HA. Ruddock *et al*[11] presented a case study of an HA programme undertaken by a referee before the 2014 FIFA World Cup, demonstrating the effectiveness of a mixed-methods approach. However, details on the training and officiating duties of the referee outside the HA programme were not provided. Typically, HA programmes involve completing multiple sessions within a short period (~7–14 days) immediately before the competition.[1 3] However, logistical challenges such as extensive travel arise when considering the programming of HA interventions for referees who are concurrently officiating in matches domestically and across Europe while also undertaking an HA programme.

The unpredictable nature of a referee's schedule is not widely appreciated. Referee appointments to matches are typically only made ~5 days before a match, and therefore, proactive planning is difficult during the acclimation window. Due to officiating duties and the associated travel, the recommended best practice of implementing supervised HA over consecutive days is not always possible. The purpose of this case study is to provide a unique insight into the schedule of a professional soccer referee while highlighting how, with careful consideration, a mixed-methods HA intervention can be implemented before the 2022 FIFA World Cup in Qatar.

METHODS

Case study

A male professional English soccer referee (age: 44 years; height: 1.82 m; body mass: 76.0 kg) who had officiated professionally for over 17 years and had over 10 years' experience officiating in European and international matches undertook an HA programme before the 2022 FIFA World Cup. The referee typically officiated 1–2 weekly matches and undertook 1–3 resistance, 1–2 sprint and 2–4 aerobic capacity training sessions. The referee had never been medically diagnosed with health illness but had previously noticed a decline in physical performance when officiating in the heat. A copy of the participant information sheet and a verbal explanation were provided before obtaining written informed consent. Ethics approval was granted by the Manchester Metropolitan University Science and Engineering Faculty ethics committee (48146).

Design

To overcome the logistical constraints of officiating duties and extensive travel during the acclimation window, the HA programme consisted of 11 sessions plus two heat tolerance tests over 22 days (18/10/2022-08/11/2022) (figure 1). The referee flew to Qatar on 09 November 2022 to undertake a 7 day referee selection and training camp (12–18 November 2022) before the tournament started on 21 November 2022. On days 1 and 22 of the HA programme, a heat tolerance test was performed, and between these tests, a mixed-methods HA approach was used. In the same 22-day period, the referee officiated in four English Premier League and two Champions League matches. To monitor training load during this period, the modified category ratio-10 (CR10) ratings of perceived exertion (RPE) scale was shown after all training sessions, including matches and the referee, was asked, 'How was your workout?' with the response indicating to the desired text descriptor on the scale.[12] The

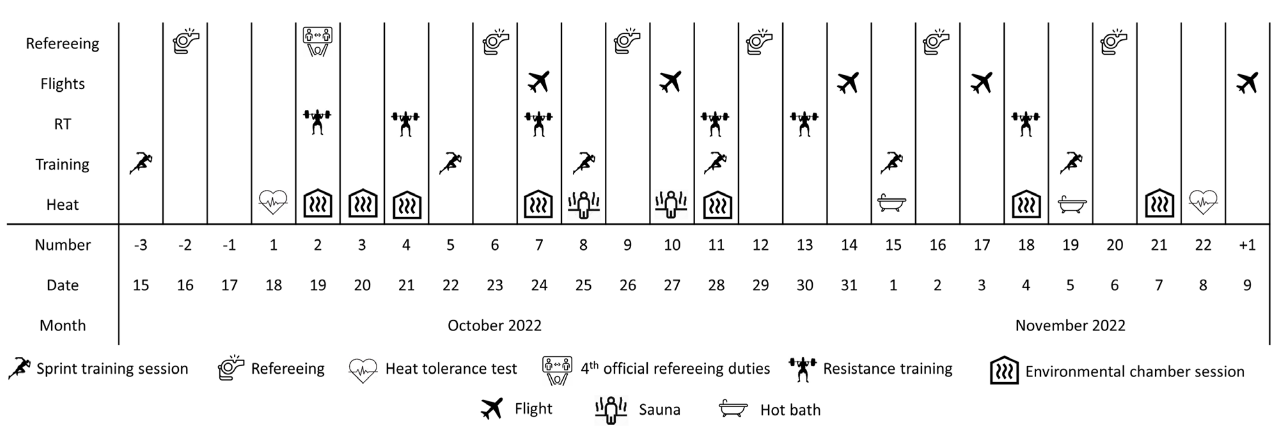

Figure 1 The referee schedule during the heat acclimation programme.

session duration was also recorded, and the two numbers were multiplied to quantify the training load (s-RPE).

Heat tolerance test

A reliable heat tolerance test[13] sensitive to heat adaptation[14] was conducted to assess changes in physiological and perceptual responses to exercise in the heat. The test entailed 30 min of running on a treadmill at 9 km.h^{-1} with a 2% gradient in 40°C air temperature and 40% relative humidity. The pre- and post-intervention tests were conducted at the same time (08:00 hours), using the same environmental chamber treadmill and with the referee wearing the same clothes. Core temperature was measured using a telemetric pill (e-Celsius performance pills, BodyCap, Caen, France), which was ingested before sleep (~11 pm) the night before the test. These pills have a standard error of measurement (SEM) of 0.039°C.[15] Skin temperature was measured using i-Buttons (DS1922L Thermochron, i-Buttons, Newbury, United Kingdom) attached at four sites via tape: arm, chest, quadricep and calf, with mean skin temperature calculated.[16] The i-buttons have a mean bias of 0.121°C.[17] The heart rate was recorded using a chest strap monitor (H10, Polar, Kempele, Finland), with the H10 model having a SE of the estimate of 0.07 b.min^{-1}.[18] The sweat rate was estimated by measuring towel-dried nude body mass before and after the test. Thermal sensation (1–7 Likert scale) and thermal comfort (1–4 Likert scale) were assessed every 5 min using standardised scales.[19] The thermal sensation scale (1=cold, 2=cool, 3=slightly cool, 4=neutral, 5=slightly warm, 6=warm, 7=hot) was shown, and the referee was verbally asked: 'How does the temperature of your body feel?'. The thermal comfort scale (1=very uncomfortable, 2=uncomfortable, 3=slightly uncomfortable, 4=comfortable) was shown, and the referee was verbally asked: 'How comfortable do you feel with the temperature of your body?'. The CR10 RPE scale was shown 30 min after the test and recorded as previously described.[12]

HA methods

In addition to the two heat tolerance tests, 11 HA sessions were performed (table 1). Due to the unknown schedule of the referee over the 22 days, daily communication occurred, with ~5 days of planning taking place at one time. There were seven isothermic exercise HA sessions performed in the environmental chamber (mean: 78 (9) minutes [range: 60–90 min]; mean: 35°C (5) [range: 30–40°C]; and mean: 51% (10) relative humidity [range: 40–70% relative humidity]). An isothermic approach was taken for the chamber-based sessions, whereby the environmental conditions were matched to the type of training planned for that day to achieve a core temperature of ~38.5°C.[20] For example, lower environmental conditions (~30°C and ~40% relative humidity) were set when performing high-intensity interval training and higher environmental conditions (~40°C and ~70% relative humidity) for a recovery day when the training session intensity and volume were lower. In addition, two 30 min post-training intermittent saunas at ~90°C (one supervised and one unsupervised) were implemented. One sauna session occurred at the same location as the isothermic sessions due to a chamber malfunction, and one sauna session in a European stadium the day before officiating in a Champions League match. Two 30 min post-training intermittent hot water immersions, where the referee was immersed up to the shoulders at ~40°C, were implemented (unsupervised). One hot water immersion session took place at the referee's home, and one while in Europe officiating a second Champions League match. The decision to use a sauna or hot water immersion was made solely based on the availability of facilities. Both the sauna and hot water immersion sessions were following training sessions, and the referee was instructed to last in the sauna or hot water for as long as safely possible at one time (~5 min), taking small breaks when needed, and accumulate a total of 30 min per session. All training sessions the referee undertook during this period were prescribed by the Head of Physical Performance (SB) at the Professional Game Match Officials Limited (PGMOL), the body responsible for refereeing in professional English soccer.

Statistical analysis

Data are presented as mean (SD) unless stated otherwise. Data from the heat tolerance tests are reported as the absolute and percentage change compared with the pre-test. The SEM [$SEM=SD \times \sqrt{1-ICC}$] and, subsequently, minimal detectable change (MDC) [$MDC=SEM\times 1.96\times \sqrt{2}$] were calculated for the heat tolerance test in all variables where the data were available.[13]

RESULTS

The referee schedule is presented in figure 1, and the HA programme details are provided in table 1. The referee reported full compliance with the HA programme. Following the HA programme peak core temperature reduced by 0.4°C (38.4 vs 38.0°C; MDC=0.34°C), peak skin temperature reduced by 0.5°C (36.7 vs 36.2°C; MDC=0.28°C) and peak heart rate reduced by 5 b·min^{-1} (167 vs. 162 b·min^{-1}; MDC=4 b·min^{-1}) in the post-test. In the post-test, the sweat rate increased by 17% (1.94 vs 2.27 L.h^{-1}; MDC=0.42 L.h^{-1}). Peak thermal sensation (7 = "hot") and the RPE (3 = 'moderate') were unchanged. However, peak thermal comfort (3 = 'slightly uncomfortable' vs 2 = 'uncomfortable') was rated lower in the post-test. The data to calculate MDC were not available for perceptual measures.[13] The change in most physiological measures from the pre- to post-test was greater than the reported MDC.[13] All data for the heat tolerance tests are presented in table 2 and figure 2. During the 22 days, there were 2 days that the referee did not complete a training session or officiate in a match, but besides this, the mean daily s-RPE was 501 (365) AU (range: 90–1080 AU).

Table 1 Heat acclimation programme

N	Type	Duration (mins)	Training intensity	Training	Environmental conditions	Mean (SD) core temperature	Maximum core temperature	Minutes spent above 1.5°C increase/38.5°C
1	Chamber	65	Medium	Treadmill 10 min @ 12 km.h^{-1} / 5 min @ 5 km.h^{-1} x 4	30 °C / 40% RH	37.53 (0.53)	38.31	16/0
2	Chamber	90	High	Treadmill 1–5 min intervals @ 15–18 km.h^{-1}	30 °C / 40% RH	38.15 (0.78)	38.99	55/44
3	Chamber	75	Low	30 min cycling (80–90 rpm) 15 min treadmill walking (5 km.h^{-1}) 30 min stretching	40 °C / 60% RH	38.03 (0.85)	38.87	48/37
4	Chamber	75	Low	30 min cycling (80–90 rpm) 15 min treadmill walking (5 km.h^{-1}) 30 min stretching	40 °C / 60% RH	Pill lost		
5	Sauna	–	–	Post-training sauna completed unsupervised	–	–	–	–
6	Sauna	75	Low	45 min cycling (80–90 rpm) interspersed with 6×5 min saunas	90°C	37.50 (0.55)	38.24	15/0
7	Chamber	75	Medium	Treadmill 35 min 15–60 s intervals @ 15–19 km.h^{-1} 40 min stretching	30 °C / 40% RH 40 °C / 70% RH	37.77 (0.85)	38.94	39/19
8	Hot water immersion	–	–	Post-training hot water immersion completed unsupervised	–	–	–	–
9	Chamber	90	High	Treadmill 1–5 min intervals @ 15–18 km.h^{-1}	30 °C / 40% RH	37.87 (0.70)	38.59	64/15
10	Hot water immersion	–	–	Post-training hot water immersion completed unsupervised	–	–	–	–
11	Chamber	30	Low	30 min cycling (80–90 rpm) 15 min treadmill walking (5 km.h^{-1}) 30 min stretching	40 °C / 60% RH	38.12 (0.82)	38.95	48/37

mins, minutes; n, number; RH, relative humidity.

DISCUSSION

The mixed-methods HA programme induced positive physiological responses, including a reduction in peak core temperature, peak skin temperature and peak heart rate in the post-test compared with the pre-test, which is greater than the MDC. The novel aspect of this case study is the presentation of the real-world practicalities of implementing an HA programme concurrently alongside the in-season schedule of a professional referee.

The decrease in peak core temperature of 0.4°C reflects the same reduction typically observed following more extensive environmental chamber-based acclimation.[21] The decrease in peak skin temperature of 0.5°C is similar to the 0.7°C reduction observed in the same heat tolerance test in male runners following an intermittent post-exercise sauna HA programme.[22] However, the same study demonstrated a greater reduction in the peak heart rate (8 b.min^{-1}; 5.3%) compared with 5 b.min^{-1} (3.0%) in the present case study.[22] The sweat rate in the present intervention was also comparable to other mixed-methods HA programmes[11] and chamber-based interventions.[20] Overall, comparisons to previous studies examining the effectiveness of HA programmes demonstrate that physiological responses reflect a similar change to those seen in this case study.

Peak thermal sensation and RPE were unchanged between heat tolerance tests. No change in RPE following a HA programme was also shown by Ruddock *et al*[11] and Gibson *et al*,[20] although a different RPE scale (6–20 Borg) was used. Peak thermal comfort was reported to be lower (ie, impaired) in the post-test compared with the pre-test. Combined with the thermal sensation and RPE findings,

Table 2 Heat tolerance tests

Measure	Variable	Pre-test	Post-test	Difference	% Change
Core temperature (°C)	Resting core temperature	36.66	36.49	−0.17	0.5%
	Mean core temperature	37.38 (0.59)	37.11 (0.47)	−0.27	0.7%
	Peak core temperature	38.40	38.00	−0.40	1.0%
Skin temperature (°C)	Resting skin temperature	33.30	32.66	−0.64	1.9%
	Mean skin temperature	35.90 (0.78)	35.49 (0.70)	−0.41	1.1%
	Peak skin temperature	36.70	36.20	−0.50	1.4%
Heart rate (b.min^{-1})	Resting heart rate	63	58	−5	8.0%
	Mean heart rate	138 (21)	135 (18)	−3	2.2%
	Peak heart rate	167	162	−5	3.0%
Sweat rate (L.h^{-1})	Whole body sweat rate	1.94	2.27	+0.33	17%
Perceptual responses (AU)	Mean thermal sensation	6.3 (0.7)	6.5 (0.7)	+0.2	3.2%
	Peak thermal sensation	7.0	7.0	0.0	0.0%
	Mean thermal comfort	3.2 (0.5)	2.5 (0.8)	−0.7	22%
	Peak thermal comfort	3.0	2.0	−1.0	33%
	Rating of perceived exertion	3	3	0	0%

Data are presented as mean (SD).
AU, Arbitrary units; b.min^{-1}, beats per minute; L, Litres.

this suggests that the HA programme might have only elicited positive physiological responses without modifying the perception of heat stress. The indifferent perceptual responses may be explained by the referee's busy schedule (figure 1) and the subsequent impact on the ability to regularly exercise in the heat and become accustomed to the sensation[1] and potentially accumulated fatigue. For example, the post-test was preceded by a busy week, including a HA session the day before, compared with a rest day before the pre-test. The decision to undertake a session the day before the post-test was made to prioritise HA and performance at the World Cup instead

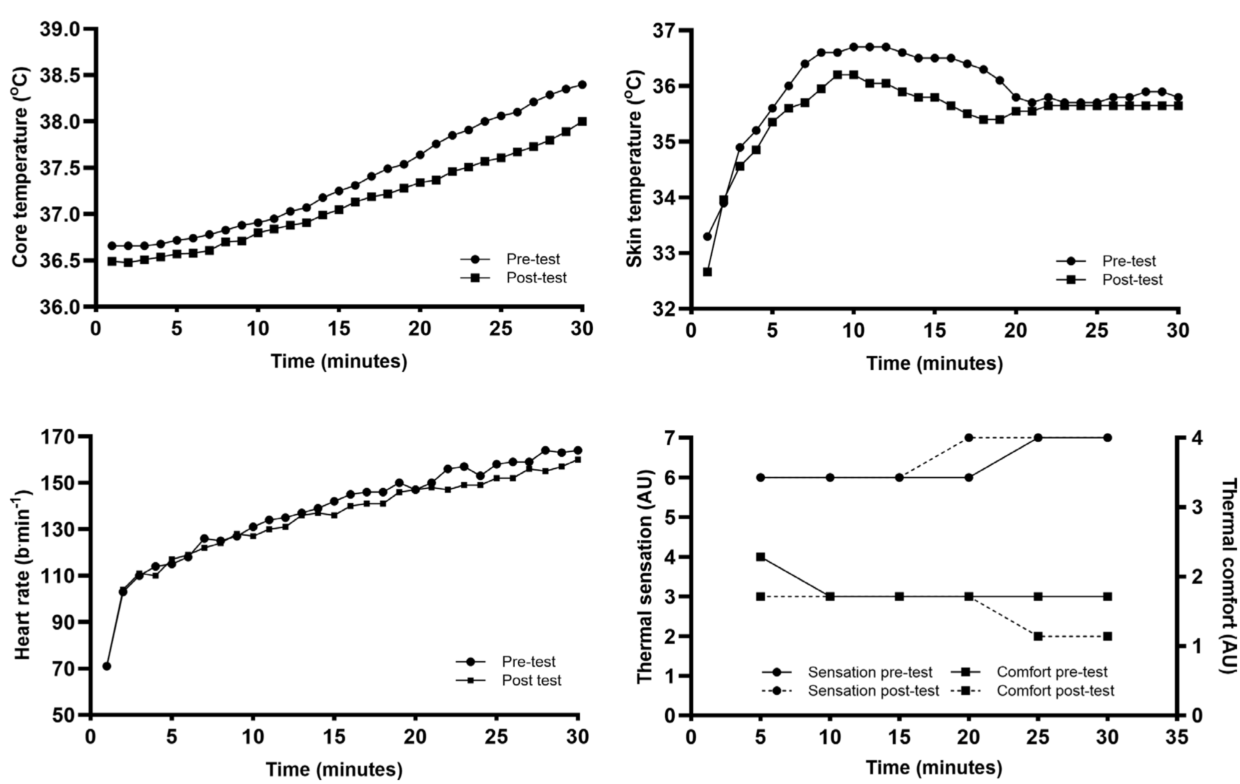

Figure 2 Heat tolerance tests.

of the post-test result. The referee anecdotally described feeling fatigued on the day of the post-test, which might explain the indifferent perceptual responses reported in the post-test, although this was not objectively measured.

Although positive HA responses were observed, the lack of data collected during the World Cup limits the demonstrable impact on refereeing performance in competition and, therefore, is acknowledged as a limitation of the current case study. In addition, some core temperature data were unavailable due to unsupervised HA sessions during periods of travel and one core temperature pill not transmitting data. In the future, researchers should look to quantify the impact of HA programmes on refereeing performance during competition and work alongside practitioners to appropriately manage the additional fatigue from undertaking an HA programme.

CONCLUSION

The mixed-methods HA programme implemented immediately preceding the 2022 FIFA World Cup elicited positive changes in physiological responses during exercise in the heat, despite the officiating and travel schedule of the professional referee. In contrast, indifferent perceptual responses were reported. Overall, this highlights that a mixed-methods HA, including low-intensity and high-intensity training sessions in an environmental chamber, post-training saunas and hot water immersion, can induce HA in individuals with a busy and unpredictable schedule.

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Contributors Conceptualisation: DBR, SB and LPB. Methodology: DBR, SB, OG and LPB. Formal analysis: DBR. Investigation: DBR, DTE, JDE and LPB. Writing—original draft preparation: DBR. Writing—review and editing: DBR, DTE, SB, JDE, OG and LPB. Visualisation: DBR, OG and LPB. Project administration: DBR. Funding acquisition: DBR and LPB. DBR is guarantor.

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Competing interests SB is employed by the PGMOL as Head of Physical Performance. The authors have no other competing interests to declare.

Patient and public involvement Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Manchester Metropolitan University Science and Engineering faculty ethics committee (48146) and was adhered to throughout. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. Access to the raw data supporting the conclusions of this article can be granted by the authors upon a reasonable request.

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