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Original research

Greater chance of high core temperatures with modified pacing strategy during team sport in the heat

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ABSTRACT

Objectives: To measure the activity profile, hydration status and core temperature of elite team sport athletes during matches in hot and cool conditions.
Design: Thirty-five professional Australian footballers (age 25.9 ± 3.5 yrs; height 188.4 ± 7.8 cm; body mass 90.6 ± 8.8 kg), gave informed consent to participate in this study. Core temperature (T_c), hydration and running performance were compared in eight hot and eight cool matches classified via a rating of the risk of heat illness from the Wet Bulb Globe Temperature (WBGT).
Methods: Core temperature was measured via an ingestible sensor before matches and after each quarter and player movement was recorded by 5 Hz GPS and expressed per period of the match (rotation), for distance; high-intensity running (HIR, 4.17–10.00 m s^{-1}), sprinting (>4.17 m s^{-1}) and maximal accelerations (2.78–10.00 m s^{-2}). All data was compared for hot and cool matches and the magnitude of effects was analysed with the effect size (ES) statistic.
Results: Core temperature was elevated from rest at all time-points during matches (37.3–39.4 °C), with small additional elevations after the first and third quarters in hot matches (ES: 0.39 ± 0.40 and 0.37 ± 0.42 respectively). In hot matches 12 players had T_c > 40 °C but only one in cool matches. Total distance was reduced in the latter parts of each half (−6.5%, −0.49 ± 0.58; and −6.7%, −0.57 ± 0.59), yet the high intensity tasks of sprinting and accelerating were preserved.
Conclusions: Players tolerated core temperatures up to 40.5 °C during hot matches but reduced the volume of running undertaken, thus preserving the ability to undertake high intensity activities.

1. Introduction

The effect of heat load on physical performance is controversial.[1,2] The rate of body heat storage may induce a feed-forward mechanism thus regulating exercise intensity;[3] but others refute this by using revised thermometric calculations of that same data.[1] The self-paced nature of exercise in team sport makes calculation of heat storage difficult.[2] It is unlikely that a critical core temperature (T_c)[4] limits exercise performance in the field;[5] yet there is increasing evidence that during self-paced exercise in the heat the pacing strategy of athletes is altered in an anticipatory manner.[6] Little is known of the pacing strategies utilised in team sport under environmental challenges, and whether team-sport athlete activity is changed with a high environmental challenge. In fact, it is unclear due to the unpredictable nature of football[7] if players can effectively pace during competition.

Australian football (AF) is a unique contact sport with a very high player activity profile,[8–10] with a long competitive season[11] requiring players to compete in a wide range of environmental conditions.[12] For example, players regularly cover up to 16 km, and accelerate maximally up to 150 times in each game,[8] thus ensuring a large metabolic cost and related heat production.[13] By comparison, elite soccer players cover distances of only approximately ~10 km,[14] or 63% of those covered by elite AF players during matches. Importantly, some soccer players may reach T_c exceeding 40 °C during matches.[15] Given the likely greater metabolic demand of AF,[10,13] players may potentially experience even larger increases in T_c than in soccer. Only one study has quantified T_c in AF players,[12] but only in a small sample of pre-season matches with a relatively low distance travelled by athletes,[8,9] and thus with a lower heat production. Furthermore,

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Table 1
Environmental conditions at the commencement of matches.

	Conditions at start of match				
	Temperature (°C)	Humidity (%)	WBGT (a.u.)	Risk of heat illness	Heat index estimated temperature (°C)
Hot					
1	30	45	28	High	32
2	27	75	30	Extreme	32
3	24	55	24	High	25
4	29	40	27	High	30
5	28	60	29	Extreme	32
6	27	86	33	Extreme	40
7	24	55	24	High	25
8	27	50	26	High	29
Mean ± SD	27 ± 2	58 ± 15	28 ± 3		31 ± 5
Cool					
1	22	50	22	Moderate	N/A
2	22	29	20	Moderate	N/A
3	19	65	<18	Low	N/A
4	13	45	<18	Low	N/A
5	17	51	<18	Low	N/A
6	14	60	<18	Low	N/A
7	12	50	<18	Low	N/A
8	13	55	<18	Low	N/A
Mean ± SD	17 ± 4	51 ± 11			

that study did not compare to matches played in cool conditions.

It is possible that modest levels of dehydration reduce the performance of team-sport athletes,[16] as T_c rises by between 0.15 and 0.20 °C for each 1% of body mass lost during an activity.[17] This T_c rise, especially when coupled with dehydration, may increase the perception of effort of players,[16] possibly leading to a reduction in effort.[18] However, if the "pacing model" is true,[6] players may have already altered their pacing to allow maintenance of high intensity efforts. Thus, AF matches, with the highest distance travelled per minute of the field sports,[10] played in a variety of environmental conditions provide an excellent model to examine both the physiological strain on players, and the activity or potential pacing response of players to matches. The aims of this study were therefore to compare the activity profile, hydration status and T_c of AF players during matches played in hot and cool environmental conditions, with specific reference to pacing strategy.

2. Methods

Thirty-five elite Australian footballers (age 25.9 ± 3.5 yrs; height 188.4 ± 7.8 cm; body mass 90.6 ± 8.8 kg at commencement of the study, [mean ± standard deviation (SD)] gave informed consent to participate in this study, which was approved by the Victoria University Human Research Ethics committee. Participants were all registered players of an Australian Football League Club. Eight players were sampled in each match, with 4 sampled in each of the 16 matches, 3 for >5 hot and cool matches, 2 for 3–5 hot and cool matches and the remaining players sampled in at least one hot and cool match. Matches were all fully sanctioned competition matches played during the pre- and regular-season competition.

Player responses were measured in eight hot and eight cool matches (Table 1), classified via a rating of the risk of heat illness from the calculated Wet Bulb Globe Temperature (WBGT). The cut-offs for classification of risk from WBGT were: WBGT < 18 °C = minimal risk; WBGT of 18–22 °C = moderate risk; WBGT of 23–28 °C = high risk; and WBGT of >28 °C = extreme risk.[19] WBGT is calculated using the following equation:

$$\mathrm{WBGT} = 0.7\mathrm{wbt} + 0.2\mathrm{bgt} + 0.1\mathrm{dt} \tag{1}$$

where wbt is wet bulb temperature (humidity), bgt is radiant heat and dt is dry bulb temperature (ambient air temperature, dt) and is expressed in arbitrary units (a.u.).

Ambient temperature and humidity prior to, and during matches were recorded at 1 min intervals using a portable weather station (Kestrel 4000 Nelson Kellerman, Boothwyn, PA, USA). Apparent temperature was calculated as the heat index (HI), incorporating both ambient temperature and humidity.[20] The HI is not calculated when ambient temperature is below 18 °C.

Core temperature (T_c) was measured via an ingestible telemetric sensor (CORTEMP^{TM} COR-100 Wireless Ingestible Temperature Sensor, HQ Inc., Palmetto, FL). Sensors were ingested by players 2–4 h prior to the first measure, as per the manufacturer's instructions and allowing for adequate transit time from the stomach. Australian football matches are divided into four playing periods known as quarters that have a duration of 20 min plus added time for natural stoppages during the game. Match measures were taken at 120 (Rest), 60, 30 and 2 min prior to the commencement of a game, and then at 1/4 time, 1/2 time, 3/4 time and as close as possible to the finish of the game.

Pre-match measures included those taken during the players' typical pre-match warm-up conducted both in- and out-doors. This warm-up featured ~40 min of activity, with some dynamic stretching, bounding and strides as well as football specific skills of kicking and handballing performed on-ground.

The precision and accuracy of a selection of sensors used in the study was confirmed by the investigator prior to use by comparing sensor temperature against a calibrated thermometer across a physiologically valid range of water temperatures in a sterile water vessel. Briefly, water temperature was titrated in the physiological range and sensor temperature compared with the thermometer. Sensors were placed in the sterile vessel in the water bath with sterile tweezers and air dried prior to subsequent use (R^2 = 0.9993).

Players in this study undertook various cooling regimes prior to the start of the first and third quarters of play, including the use of cooling vests, ice packs applied to the head and neck and approximately 5 min spent in a cool room at approximately 8 °C.

Player activity profile was measured via GPS sampling at 5 Hz (MinimaxX Team Sports 2.0, Catapult Innovations, Melbourne, Australia). The activity profile variables analysed, expressed in metres per minute of match time (m min^{-1}) were: Total distance; high-velocity running (HiVR, 4.17–10.0 m s^{-1}) and sprints