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Research article

Physiological responses of elite junior Australian rules footballers during match-play

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Abstract
Australian Football (AF) is Australia's major football code. Despite research in other football codes, to date, no data has been published on the physiological responses of AF players during match play. Fifteen athletes (17.28 ± 0.76 yrs) participated in four pre-season matches, sanctioned by Australian Football League (AFL) Victoria, investigating Heart Rate (HR), Blood Lactate (BLa), Core Temperature (Tcore), and Hydration status. Match HR was measured continuously using HR monitors. BLa was measured via finger prick lancet at the end of each quarter of play. Tcore was measured by use of ingestible temperature sensor and measured wirelessly at the end of each quarter of play. Hydration status was measured using refractometry, measuring urine specific gravity, and body weight pre and post-match. Environmental conditions were measured continuously during matches. Results of HR responses showed a high exertion of players in the 85-95% maximum HR range. Elevated mean BLa levels, compared to rest, were observed in all players over the duration of the matches ($p = 0.007$). Mean Tcore rose 0.68 °C between start and end of matches. Mean USG increased between 0.008 g/ml ($p = 0.001$) with mean body weight decreasing 1.88 kg ($p = 0.001$). This study illustrates physiological responses in junior AF players playing in the heat as well as providing physiological data for consideration by AF coaching staff when developing specific training programs. Continued research should consider physiological measurements under varying environments, and at all playing levels of AF, to ascertain full physiological responses during AF matches.

Key words: Australian football, junior athletes, competition, cardiovascular, heat stress, thermoregulation.

Introduction

It is now accepted that the general physical demands of team sports involve prolonged exercise periods comprising of frequent high intensity bursts interspersed with low intensity recovery periods (Shireffs, 2005). Recent time-motion studies in Australian Football (AF) at the senior (Dawson et al., 2004) and junior levels (Veale et al., 2007) have further supported this suggestion. However, consideration of conditioning for team sports such as football requires an understanding of the sport-specific physiological match demands experienced by athletes within each code (Bangsbo et al., 2006). Indeed, various physiological studies, at different levels of competition, have been conducted across a number of football codes including soccer (Reilly, 1997), rugby union and league (Coutts et al., 2003; Deutsch et al., 1998), and American (Godeck et al., 2004) and Gaelic football (Reilly and Keane, 2002). Measurement of match demands, in these studies, have specifically focused on heart rate (HR), usually expressed as a % of maximal heart rate (HRmax), blood lactate (BLa) and, more recently, core temperature (Tcore). These physiological variables have yet to be examined in Australian Football (AF).

To date, HR and BLa data presented in various codes of football research have suggested that the mean exercise intensity is close to anaerobic threshold (Hoff, 2005). The anaerobic threshold determines the highest workload, oxygen consumption or heart rate in dynamic work using large muscle groups, where production and elimination of lactate are balanced (Hoff, 2005). Theoretically, a higher anaerobic threshold would enable the maintenance of a higher average intensity in an activity prior to the onset of fatigue (Hoff, 2005). Bangsbo et al. (2006) reported in elite soccer, mean BLa concentrations of 4.1 and 2.4 $mmol.l^{-1}$ for first and second halves respectively. In Gaelic football (GF), which most closely resembles Australian football (AF; Reilly and Doran, 2001), Florida-James and Reilly (1995) found mean first and second half BLa concentrations of 4.3 and 3.4 $mmol \cdot l^{-1}$. However, studies have also shown significant differences in HR and BLa responses between different playing positions in rugby union (Deutsch et al., 1998) and between adolescent and adult soccer players (Billows et al., 2005), demonstrating position-specific and age-specific influences. Moreover, game intensities can frequently exceed players' anaerobic threshold since repeated sprint ability is an important performance indicator for team sports (Bishop et al., 2001). Examples of this can be found by Coutts et al. (2003), who found mean HR corresponding to 93% and 81% of maximal HR respectively. Gaelic football has presented mean HRs during match play of approximately 80% of HRmax (Florida-James and Reilly, 1995; Reilly and Keane, 2002) in club and elite players.

Despite the less invasive nature of Tcore monitoring via wireless telemetry to other forms of core temperature measurement methods, monitoring of Tcore via wireless telemetry in the football codes has been restricted, possibly due to the practical limitations in player access during match-play. Limited published studies have been completed in American football match practice, showing fluctuating increases in Tcore from 37.2 – 38.6 °C (peaking at 39.1 °C) reflecting the intermittent nature of the exercise (Godek et al., 2004). Edwards and Clark (2006) studied recreational and professional soccer players, showing significant increases in Tcore between pre-match (36.9 °C) to half time in the professional players (38 °C),

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and between pre-match (37.1 °C) to half-time (38.5 °C) and between half-time (38.5 °C) to full-time (39.1 °C) in recreational players.

Hydration status can by measured using refractometry, with many studies validating the use of refractometry via the measurement of urine specific gravity (Armstrong et al., 1994; Casa et al., 2000; Pearce et al, 2008). Bangsbo et al. (2006) reported dehydration as a possible contributing factor to the development of fatigue in the later stages of a soccer match. Alternatively, Magal et al. (2003) have shown a decrease in 5 m and 10 m sprint times when in a hypohydrated state of 2.7% body mass in tennis players. Pre-match to post-match bodyweight (BW) comparison is also used as an indicator of hydration status. Under match conditions, previous studies have shown a mean loss of between 1.5 to 2% of BW in soccer (Ekblom, 1986; Edwards and Clark, 2006) and mean BW change of elite adult AF players of 1.13% (Quinn et al., 2007). Similar findings of loss in BW have also been shown in tennis where professional players in competitive matches have lost between 0.27% to 2.9% of their BW post match (Pearce, 2008).

Without sport-specific published studies as reference, many AF junior coaching staff preparing and prescribing training loads for their players have relied on personal experience, anecdotal observations or research from other football codes, as outlined in this introduction, and generally adapting these findings to AF rather than evidence-based research. Therefore, this study measured HR, BLa and Tcore responses during elite junior AF matches, presenting data for consideration by coaching and fitness staff of junior AF squads when designing sport specific fitness programs.

Methods

Participants

Fifteen junior male players (17.28 ± 0.7 years) from one squad that participates in the Victorian elite junior AF (Under 18) competition took part in the study. All players and parents gave written informed consent and the study was approved by the University Human Ethics Committee conforming to the Code of Ethics of the World Medical Association (Declaration of Helsinki). Data was collected during four organised interclub pre-season matches in March 2006, after the completion of a three month pre-season training period involving three training sessions a week (range of 4-6 hrs/wk). Typical training sessions involved 20 min of specific conditioning work (aerobic / anaerobic running) and 80-100 min of skills training. Training duration and intensity was decreased in the two weeks prior to the practice match period to taper for the upcoming competitive season. During the practice matches, players only participated in two of the four games (one game per week), as two games were scheduled on the same day (game one in the morning, game two in the afternoon) over two consecutive weekends. Although results of matches were not recorded, players were assumed to be committing a full effort towards winning the match. In this study, players completed a mean game time of 82 ± 6 min in comparison to the available 100 min game duration.

All matches were sanctioned by Australian Football League (AFL) Victoria, conforming to rules set by the AFL, and were against teams within the elite junior competition.

Environmental conditions

Measurements of environmental conditions at 10 min intervals were conducted using an environmental measurement monitor (Kestrel 3000, Nielsen-Kellerman, USA). Conditions monitored throughout the matches were: ambient temperature as measured by dry globe bulb temperature (DBGT); relative humidity (RH), heat stress index (HSI) as measured by wet bulb globe temperature (WBGT) and wind speed.

Physiological variables measured

Heart rate was recorded throughout the match at 5 s intervals using a standard heart rate monitor (Polar Accurex Plus, Polar Electro, Finland). To account for the physical nature of ARF, the HR chest strap was encased in an adapted rugby sternum protector vest (Reliance, Taiwan) and worn underneath the athlete's jersey (Figure 1). The sternum protector is designed to be well-ventilated. Closed cell foam padding (10mm thick) provided protection around the sternal region, directly over the chest strap, whilst nylon eyelet material ensured that the vest was lightweight and comfortable to wear, allowing for the dissipation of body heat. The watch receiver was placed inside a specially designed padded pouch that was strapped around the upper limb of the dominant arm using Velcro straps (Figure 1). The dominant arm was chosen as each athlete reported a tendency to use their non-dominant side during match related physical confrontations with opposing players. All watches were started simultaneously and a continuous timer was used to mark the start and end times of each quarter for later analysis.

Figure 1. Sternum protector vest and protective arm strap used during each match.

Following each match, data from each watch was downloaded (Polar Precision Performance 2.0, Polar Electro, Finland) and exported to an Excel Worksheet (Microsoft Corporation, USA), where only data recorded during each quarter was categorised into pre-determined HR zones (Deutsch et al., 1998), describing exercise intensity as "low" (<75% HRmax), "moderate" (75-84% HRmax), "high" (85-95% HRmax) and "max" (>95% HRmax). HRmax was taken to be the highest achieved

HR during match-play (Deutsch et al., 1998).

Blood lactate sampling was performed on site using portable BLa analysers (Arkray Co., Japan). These portable BLa analysers have been previously validated for field-based research (Pyne et al, 2000). Samples were taken via finger prick lancet prior to the match and at the completion of each quarter of the match.

Hydration status was determined using hand-held refractometry (Atago Co., Japan). Each participant was instructed to provide a small "clean-catch" (midstream) urine sample into a sterile container prior to and at the first opportunity to void following the completion of the match.

Each player's internal Tcore was measured using wireless telemetry (HQ Inc, USA; Figure 2a and b). This technology has been previously validated (O'Brien et al, 1998). Players selected to be tested on the morning of the match swallowed the one-use only silicone coated "pill" (22 mm long, 11 mm diameter; Figure 2a) approximately 6 h prior to play. The pill contained a crystal sensor that vibrates at a frequency proportional to body temperature and emits a signal detected by a hand held monitor (HQ Inc, USA; Figure 2b) providing an immediate measure of a player's Tcore prior to the match and at the completion of each quarter of the match.

Figure 2. (a) CorTempTM core body temperature sensor pill; and (b) measurement of a player in-match.

Data analyses

Descriptive data is used to present environmental conditions. Comparisons of mean HR, BLa, hydration and body weight between first and second halves were conducted using Wilcoxon-Signed Ranks tests. Friedman's ANOVA with Wilcoxon post hoc tests and Cohen's (1988) effect sizes were performed to compare HRmax zone and Tcore differences over the course of the four quarters of the matches. Significance was set at $p < 0.05$. HR values were rounded to the nearest whole number and all results are presented as mean (± SD).

Results

Environmental conditions

All matches were played in dry conditions. Environmental conditions experienced over the four matches showed varying ambient temperature ranges. Ambient temperatures taken during day one ranged from 25.0 to 31.4 °C and day two ranged from 20.1 to 26.8 °C. Heat Stress Index ranged from 30.0 to 33.9 ºC during day one and 20.5 to 24.8 ºC during day two. RH ranged from 42.0 to 66.0% and 47 to 63.7% on days one and two respectively. Wind speed ranged from 4.0 to 5.4 km/h and 4.6 to 5.8 km/h on days one and two respectively.

Table 1. Group (n = 15) mean (±SD) physiological variables recorded in players.

		1st Half		2nd Half	
Heart Rate (bpm)		173 (8)*		163 (16)	
	Rest	**1st Qrt**	**2nd Qrt**	**3rd Qrt**	**4th Qrt**
BLa	2.5 (.9)*	8.7 (4.3)	9.2 (6.1)	7.5 (3.8)	8.2 (4.0)
Tcore (ºC)	38.3 (.3)	38.9 (.2)	39.0 (.2)	38.7 (.6)	39.0 (.1)
		Pre-match		**Post-match**	
Hydration ($g·ml^{-1}$)		1.010 (.007)		1.018 (.008) *	
Body weight (kg)		79.3 (7.7)		77.8 (7.6) *	

* indicate significant difference. BLa = blood lactate ($mmol·l^{-1}$).

Physiological variables

Group mean HR data showed a significantly higher HR of 10 beats per minute (bpm) during the first half compared to the second half ($p = 0.01$, ES = 0.75, Table 1). Percentage of match time within HRmax zones (Figure 3) showed a significant difference ($p < 0.001$) with post-hoc analyses illustrating that players spent most time in the 85 - 95% HRmax range compared to less than 74% HRmax ($p = 0.002$, ES = 4.2), 75-84% HRmax ($p = 0.016$; ES = 2.7), and 95-100% HRmax ($p = 0.001$, ES = 6.8). More than half of the total match time was spent in this HR range during the first half (55±15%), decreasing to 42±21% in the second half. Increases in the time spent in the < 74% HRmax range and the 75-84% HRmax range were seen in the third and fourth quarters. The least amount of time was spent at the 95-100% HRmax range compared to the other HRmax levels. Time spent in this zone was between 8±14% and 10±12% in the first two quarters of the first half, decreasing to 2±13% in the second half.

Group mean BLa data showed significant increases above resting levels ($p = 0.007$; Table 1), and throughout match play conditions, BLa levels remained elevated. Lactate values obtained in the second quarter were elevated by 5.7% when compared to the first quarter (ES = 6.9), whilst values obtained in the fourth quarter were 9.3% greater when compared to the third quarter (ES = 5.4; Table 1).

An increase in group mean Tcore results was observed from resting to playing, however no significant increases in Tcore were seen at the end of each quarter (ES = 0.2), despite higher group mean results occurring in the second quarter of each half (i.e. 2nd quarter and 4th quarter, Table 1).

A significant change in urine specific gravity from pre to post match was seen (P=0.001, Table 1). While three players recorded positive hydration changes (ranging from 0.003-0.01 $g·ml^{-1}$), the hydration changes ranged from a 0.003 $g·ml^{-1}$ increase to a loss of 0.22 $g·ml^{-1}$. Table

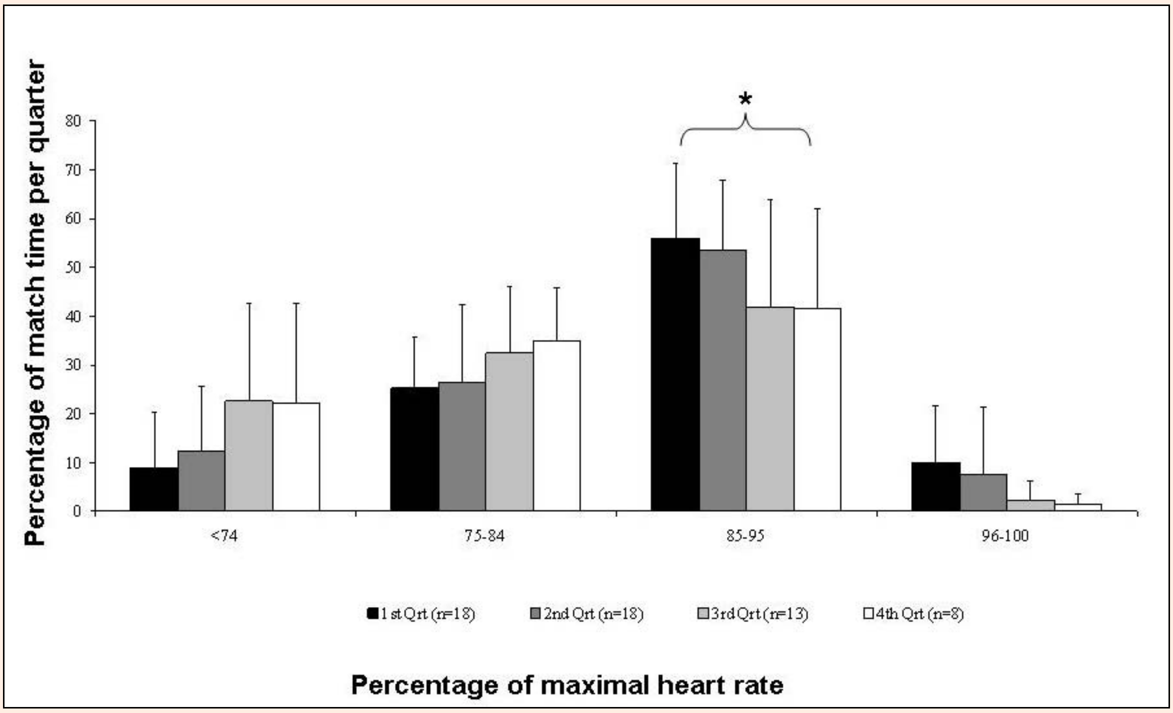

Figure 3. Mean (±SD) percentage of match time per quarter spent within %HRmax zones across all position categories. Number of athletes measured are indicated next to legend. * indicates significant difference to other HR zone data points for each quarter.

1 demonstrates a significant decrease in post-match body weight ($p = 0.001$). The mean loss across the group was 1.53 kg (range = 0-3 kg).

Discussion

This study has presented physiological data gained from fully sanctioned pre-season matches. To our knowledge, this is the first time that data of this nature, at any level, have been presented in Australian football (AF). Whilst it is acknowledged that game result and stage of season will pose a potential impact on individual player performances, the aim of this study was to investigate and present physiological response to a competitive elite junior AF match.

It is well known that the demands of AF require high volumes of running, generating distances run between 10 to 16 kms per match, at both senior and junior levels (Dawson et al., 2004; Veale et al., 2007). However these distances, gained from time-motion analysis studies, are made up of a number of high intensity running and sprinting efforts interspersed with active recovery movements such as jogging and walking (Dawson et al., 2004; Norton et al., 1999; Veale et al, 2007). The HR data observed in this study, showing the greatest amount of time in the 85% HRmax zone, demonstrates the highly anaerobic nature of AF and implies a large contribution of energy above anaerobic threshold levels (Deutsch et al., 1998). Consequently, using HR monitors and intensity zones as a training tool, high intensity training stimuli including repeated fast-running (and sprinting) efforts interspersed with brief recovery intervals may be an effective method of building game specific fitness (Dawson et al., 2004).

Given the population sample measured (being junior athletes), high HRs are not unexpected, as demonstrated by previously published differences in HR responses between adolescent and adult populations (Billows et al., 2005). Similarly, high BLa results demonstrate that AF depends on a greater reliance of anaerobic sources of energy to provide high intensity bursts with aerobic metabolism playing a secondary role in recovery (Norton et al., 1999). Our findings reporting decreases in HR and BLa in the second half of matches concur with the results of previous studies in Rugby League (Coutts et al., 2003) and Soccer (Billows et al., 2005). These results must be read with caution as the matches analysed were played during the pre-season practice-match competition phase. In addition, individual fitness, emotional stress, time of blood measurement and environmental conditions have been shown to impact on BLa results obtained during competitive sporting matches (Coutts et al., 2003).

An increase in mean Tcore from rest to play was observed concurring with recent findings in soccer match play by Edwards and Clark (2006). However, elevated Tcore did not change across the four quarters. The matches recorded in this study were played in March (Australian autumn), prior to the regular season of April to September, which may have influenced the Tcore results. Despite AF being considered a “winter sport”, teams train over summer (November to January) and play pre-season competitions during the months of February and March, with heat strain being an important factor when considering the health and safety of players. It is suggested that coaches and fitness staff (if possible) monitor Tcore of their players during training sessions during the summer months.

Notably, the recorded decrease in body weight (group mean change of 2% in body weight), coupled with the increase in urine specific gravity, suggest that the players were dehydrated at the end of the matches (Magal et al., 2003; Reilly, 1997). Although dehydration did not appear to affect mean HR in this study, which has been previously shown in laboratory studies to increase when an individual becomes dehydrated (Gonzalez-Alonso et al., 1997), it may have contributed to fatigue, as seen in declines in mean HR and BLa responses, in the second half of the match. Quinn et al. (2007) reported a decline in match performance, measured by the number of effective possessions completed (kicks and hand-passes that reached their intended target), in elite adult AF players when body weight was reduced by over 3%. Although a small percentage (2%) of players recorded greater than 3% loss in BW, the authors found a significant relationship between change in BW in these players and decrement in performance over matches during the regular AF season. Furthermore, previous research has suggested a link between hypohydration rates in tennis players amounting to 2.7% of body mass decreasing sprint times over 5 and 10 m (Magal et al., 2003). Whilst muscle glycogen depletion has also been suggested to negatively impact single and repeated sprint performance in team sports (Bangsbo et al., 2006), the changes in body weight and urine specific gravity in this study will aid in the planning and implementation of appropriate pre-training and game-day nutritional strategies for improved performance. Future research would combine the techniques used within this study and the monitoring of fluid consumption during the game to provide further information when measuring the effect of hydration status on individual game performance.

Conclusion

In conclusion, this study has shown that collecting physiological data during sanctioned matches can be obtained, giving coaching and fitness staff valuable specific information on which to base their preparations on. Further, data from this study has also been used as an educational tool for junior players, assisting to prepare themselves appropriately prior to the regular season. It is important to conduct "in-match" data research at all levels of AF in both pre- and regular season, as well as intervention studies such as the effects of cooling techniques and quarter-time recovery activities, adequate pre-match hydration and fluid replenishment during matches to maintain match performance. Future research could investigate the existence of position specific physiological responses in line with previously published movement pattern analysis results (Dawson et al., 2004; Veale et al., 2007).

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Key points

- Specific conditioning sessions for junior athletes should include high intensity bouts; greater than 85% of heart rate maximum zone.
- Football anaerobic conditioning activities (e.g. sprint training) should be randomised throughout training sessions to replicate demands of the game (e.g. training in a fatigued state).
- Coaches and fitness staff should provide education and player management strategies for fluid replacement at key opportunities (pre-match, formal breaks and substation on and off the field) during matches.

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