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Original paper

Match running performance in elite Australian Rules Football

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Abstract

There is little information describing the match running demands of elite-level Australian Rules Football (AF). The aims of this study were to examine: (1) match running demands; and (2) the influence of periods of increased physical activity on subsequent running performance in the Australian Football League. Time-motion analyses were performed 1–9 times per player from 16 professional AF players from the same club during games in 2005–2007, using portable global positioning systems during 65 matches. Game movements (standing, walking, jogging, running, higher-speed running, and sprinting) and distances (total distance covered [TD]; low-intensity activity [LIA, distance <14.4 km h^{-1}]; and, high-intensity running distance [HIR, distance > 14.4 km h^{-1}]) were collected. The influence of the first half physical activities on second half activities, and each quarter on the subsequent quarter were analysed. The mean (±SD) TD and HIR distance covered during the games were 12,939 ± 1145 m and 3880 ± 663 m respectively. There were reductions in TD in the second (−7.3%), third (−5.5%) and fourth (−10.7%) quarters compared to the first quarter (p < 0.01). The HIR was reduced after the first quarter (p < 0.001). Players that covered larger TD or HIR during the first half or quarter decreased distance in the next half and quarter, respectively (p < 0.001). These results show that a reduction in exercise intensity is inevitable during an AF match and that higher intensity activities reduce towards the end of games. High average speed during each half or quarter also affects subsequent running performance in elite-level AF.

Keywords: Match analysis; High-intensity running; Team sport; Intermittent exercise

1. Introduction

Australian Rules Football (AF) is a popular sport in Australia. The elite competition, the Australian Football League (AFL) draws the largest public support and television audience of any sport in the country. There have been few peer-reviewed research studies that describe the match activity profiles of elite-level AF players.[1–3] Indeed, Dawson et al.,[1] estimated from video analysis that top-level players cover between 10,761 m and 18,801 m during a game with midfielders covering the greatest total distance in games (∼17,000 m), and the full forwards and fullbacks travelling the least (∼13,600 m). These estimated distances compare well with Norton et al.,[4] who used real-time hand computer tracking of players in a commissioned report on AFL matches (20 midfielders covered an average of ∼17,500 m), but are considerably greater than earlier reported distances using manual player tracking methods (∼4000–11,000 m).[5,6]

Portable global positioning system (GPS) devices are now permitted to be worn by players during AFL matches and these are used by all teams competing within the AFL. Indeed, the AFL now commissions time-motion research projects annually and a large database of match GPS data is collected each season.[7–10] These reports have shown that elite-level AFL players have reduced the distances travelled during a game from 12,450 ± 1650 m to 12,180 ± 1890 m[10] from 2005 to 2008. The amount of time spent on the field during matches for these players has also decreased from 111 ± 14 min to 100 ± 14 min during the same period,[10] resulting in an increased average speed. Variations of physical activity profiles have also been reported between positional

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roles and within quarters. Specifically, players who competed as fixed forwards ($N = 121$) and fixed backs ($N = 122$) covered $11{,}920 \pm 2080$ m and $11{,}880 \pm 1920$ m, respectively, whilst the remaining 'nomadic' players covered $12{,}310 \pm 2010$ m ($N = 1153$). It was also shown that the 'nomadic' players travel at a faster mean speed than the other positions and spend less time on the field during a match than the other positions.[10]

Between-quarter variations have also been observed in the physical activity profile of AFL players, with the greatest distances travelled during the first quarter (3070 ± 630 m) and a moderate reduction being reported in the fourth quarter (2840 ± 630 m).[10] A similar trend in the mean speed has also been reported with speeds of $7.66 \pm 0.85\,\text{km h}^{-1}$, $7.37 \pm 0.77\,\text{km h}^{-1}$, $7.33 \pm 0.80\,\text{km h}^{-1}$, and $7.10 \pm 0.88\,\text{km h}^{-1}$ shown for the first, second, third, and fourth quarters, respectively.[10] Unfortunately, the data from these AFL reports have not been peer-reviewed and the time and distance data has been obtained from different GPS devices which make analysis and interpretation of the results difficult.[11] It has been shown that measures between different GPS devices of the same model can differ 32.4% for high-intensity running ($>14.5\,\text{km h}^{-1}$) and 6.4% for total distance during team sport running patterns.[11] Consequently, it has been suggested that results from different GPS units should not be used interchangeably, especially when analysing high-intensity running.[11,12]

At present there is little detailed information describing match demands at the elite level, or variations in physical activity patterns during an AF match. Therefore, the aims of this study were to describe the match running demands of AFL players and to examine the influence of periods of intense exercise on subsequent physical activity in the AFL. It was hypothesised that high-intensity running performance would decrease during matches and that periods of intense exercise would be followed by periods of reduced performance.[13]

2. Methods

Time-motion analysis of physical performance was collected from 16 professional Australian football players (age: 23.9 ± 3.1 years, body mass: 86.3 ± 8.1 kg, and stature: 187.5 ± 5.3 cm) from the same club. The team finished 13th (2005), 15th (2006) and 12th (2007) out of 16 teams competing in the AFL during the seasons analysed. Players were measured in a number of different positions and their role within the team structure may have changed during the games analysed. The methods for study were approved by a university ethics committee and by the AFL club involved.

Time-motion analyses were performed 1–9 times on each player. Data was collected from 25 different official matches (1–4 samples per game) for a total of 79 individual samples. The time-motion data was only included in the analysis if the player participated > 75% of total match time, which provided 65 complete data files.

Match distance and speed were collected at 1 Hz using a portable GPS device (SPI 10, GPSports, Canberra, Australia) and reduced using proprietary software (GPSports Analysis v1.6, GPSports, Canberra, Australia). During games, the players wore the same GPS devices in a custom-made pouch fitted between their scapulas. This GPS device has previously been shown to provide valid measures for distance at an acceptable level of accuracy and reliability for total distance ($-4.1 \pm 4.6\%$ of true distance) and peak speeds (coefficient of variation $\pm$ 90% confidence interval: 5.8% (5.2–6.6%)) during high-intensity, intermittent exercise, but poor inter-unit reliability for distance travelled at higher intensity activities (32.4% for high-intensity running distance [$>14.4\,\text{km h}^{-1}$, HIR]).[11]

Changes in game movements and distances were analysed during each quarter of match play using the pooled data of all 65 data files.

Game movements: The time spent and distances covered in six locomotor categories [standing (0–0.7 km h^{-1}), walking (0.7–7 km h^{-1}), jogging (7–14.4 km h^{-1}), running (14.4–20 km h^{-1}), higher-speed running (20–23 km h^{-1}), and sprinting ($>23\,\text{km h}^{-1}$)] were calculated.

Match distances: Total distance covered (TD), low-intensity activity (LIA) distance ($<14.4\,\text{km h}^{-1}$); and HIR distance ($>14.4\,\text{km h}^{-1}$) were calculated. The frequency of HIR and the highest speed recorded during the game for each player were recorded. These speed zones were selected as they reflect the zones previously reported in recent time-motion analysis literature in field-based, team sports.[13–15] The frequency of high speed zone entries (sprints $> 23\,\text{km h}^{-1}$) and the highest speed recorded during the game were also collected. Average speed (m min^{-1}) was also calculated from the distance covered in each quarter divided by the time spent on the ground for each individual player.

According to the methods previously described,[13] the individual player data ($N = 65$) for TD during the first half were divided into two subsets (i.e. 'High' and 'Low', median split technique, $N = 32$) based on physical activity in the first defined period (i.e. first half or defined quarter) to examine the effect of physical activity measures during each following period. The same procedure and analysis was applied using the TD, HIR and average speed data during the first half or defined quarter, to examine the influence of that physical activity on the physical activity during the following half or quarter.

Data are presented as the mean $\pm$ standard deviation (SD). Before using parametric statistical test procedures, the assumptions of normality and sphericity were verified. Statistical significance was set at $p < 0.05$.

A one-way analysis of variance (ANOVA) for repeated measures was used to test the differences in the objective measures of match running performance (game movements, match distances and other match analysis measures) between

Table 1
Measures of match running performance during each quarter (mean ± SD).

Variable	1st	2nd	3rd	4th
Game movements (time)				
Stand (s)	179 ± 116	242 ± 169	241 ± 170	221 ± 259
Walk (s)	955 ± 152	952 ± 187	988 ± 157	1010 ± 185
Jog (s)	422 ± 75	378 ± 76[a]	377 ± 71[a]	371 ± 95[a]
Run (s)	156 ± 41	139 ± 33	138 ± 39	119 ± 33[a]
Higher-speed running (s)	44 ± 17	40 ± 15	40 ± 15	36 ± 13
Sprint (s)	25 ± 10	21 ± 10	21 ± 11	18 ± 10[a]
Game movements (distance)				
Walk (m)	1130 ± 201	1070 ± 214	1130 ± 202	1130 ± 228
Jog (m)	1121 ± 267	1096 ± 218[a]	1096 ± 266[a]	1049 ± 242[a]
Run (m)	675 ± 158	619 ± 152	610 ± 175	525 ± 145[a,b,c]
Higher-speed running (m)	242 ± 95	220 ± 87	221 ± 85	198 ± 74
Sprint (m)	168 ± 73	142 ± 68	140 ± 78	121 ± 66[a]
Match distances				
TD (m)	3463 ± 403	3186 ± 461[a]	3232 ± 460[a]	3058 ± 433[a]
HIR (m)	1090 ± 212	980 ± 219[a]	971 ± 256[a]	844 ± 198[a,b,c]
LIA (m)	2380 ± 324	2210 ± 333	2260 ± 341	2210 ± 352
Other				
Average speed ($\mathrm{m\,min^{-1}}$)	117 ± 14	108 ± 15[a]	108 ± 17[a]	103 ± 14[a]
Sprint number	7.7 ± 2.6	7.2 ± 3.1	7.5 ± 4.7	6.2 ± 2.8
Peak speed ($\mathrm{km\,h^{-1}}$)	29.1 ± 1.9	28.4 ± 1.8	28.0 ± 1.9[a]	28.4 ± 2.0

TD = total distance; HIR = high-intensity running distance; LIA = low-intensity activity distance; peak speed = highest speed recorded during the quarter.
[a] Significantly different to first quarter.
[b] Significantly different to second quarter.
[c] Significantly different to third quarter.

the four quarters. To control the Type-I error, an operational α level of 0.008 ($p < 0.05/6$) was used for F values. When a significant F value was found, Bonferroni's post hoc tests were applied.

A two-way mixed ANOVA (2 × 2 design) was used on each dependent variable to examine the effect of the amount of physical activity completed in one period of play (i.e. half or quarter) on the physical performance measures in the next period. The independent variables included one between-subject factor (amount of physical activity in the defined period) with two levels (High and Low), and one within-subjects factor (time) with two (first and second half) or four levels (first, second, third and fourth quarter). When a significant F value was found Bonferroni's post hoc tests were applied.

3. Results

The mean TD, and HIR distance covered during the games were 12,939 ± 1145 m and 3880 ± 633 m, respectively. Players completed 28.6 ± 8.1 efforts above 23 $\mathrm{km\,h^{-1}}$ during each match with the mean peak speed achieved during each match being 30.2 ± 1.5 $\mathrm{km\,h^{-1}}$. Table 1 shows the time-motion measures during each quarter. There were reductions in TD in the second, third and fourth quarters compared to the first quarter ($p < 0.01$). The HIR distance during the fourth quarter was less than the first quarter ($p < 0.05$). There were no differences in the duration of each quarter (1st quarter = 29.7 ± 1.8 min, 2nd quarter = 29.5 ± 2.0 min, 3rd quarter = 29.9 ± 1.8 min, and 4th quarter = 29.6 ± 1.9 min, $p = 0.49$).

Figs. 1 and 2 show significant interactions for distance (High vs. Low) × time were found for first half match, first quarter, second quarter, third quarter and fourth quarter ($p < 0.001$). Players that covered the larger amount of TD, or HIR during the first half (Fig. 1), or quarter (Fig. 2), decreased match distances in the next half and quarter, respectively. In contrast, players that covered the smaller amount of TD or HIR in the first half did not decrease their performance in the second half.

Fig. 3 shows the speed attained in HIR was unchanged as the game progressed, however, the mean speed in LIA was decreased following the first quarter ($p < 0.001$). Table 1 also shows that time spent in HIR decreased after the first quarter ($p < 0.001$).

4. Discussion

This study described the within-match variation of physical activity demands in elite-level AF. Results show that the physical activity profile changes as the match progresses. Specifically, there was a reduction in total distance and HIR travelled after the first quarter. There was also a reduction in the average speed travelled during LIA following the first quarter, but no change in the mean intensities achieved whilst in the HIR zone. These results show that higher physical demands during the early periods of the match

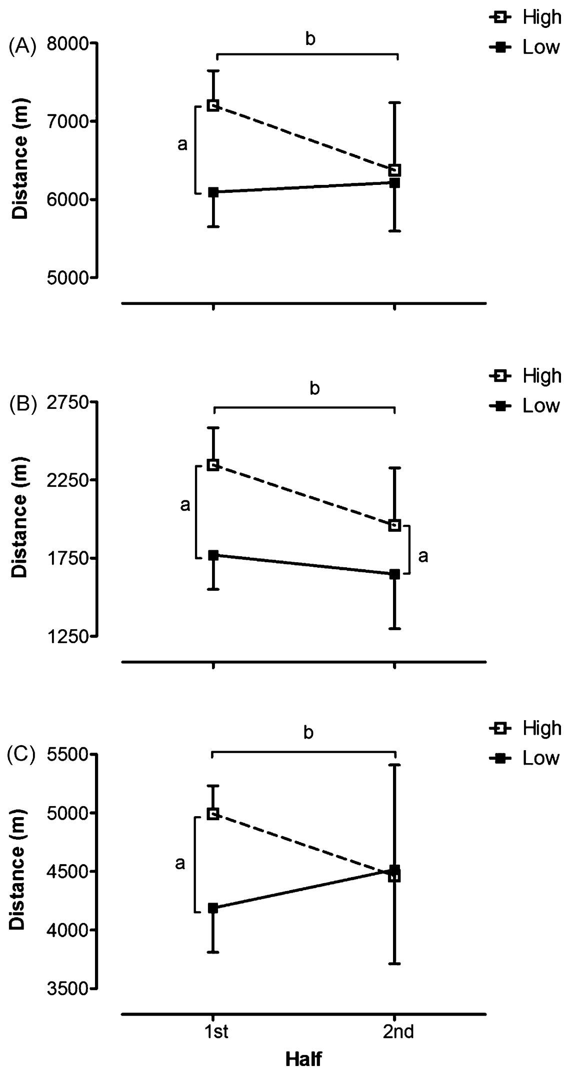

Fig. 1. Effect of first half exercise intensity on second half exercise intensity (mean ± SD) for (A) Total distance (m), (B) High-intensity running distance (m); and, (C) Low-intensity activity distance (m). High (□), players that travelled above the median value for the pooled data ($N = 32$), Low (■), players that travelled below the median value for the pooled data ($N = 32$). Interactions were significant for all four variables ($p < 0.001$). [a]significantly different between High and Low group ($p < 0.05$), [b]significantly different between first and second half ($p < 0.05$).

may influence the onset of fatigue towards the end of the match.

The general physical activity profile of AF players in this study is similar to previous peer-reviewed research,[1,3] and recent AFL research reports.[7–10] Unfortunately, the only comprehensive peer-reviewed study on the time-motion demands of AF during the competition season used video analysis to estimate physical activity profiles[1] and therefore caution must be taken in comparing results.[16,17] Nonetheless, it seems that the TD travelled by the players in this study may be slightly higher than the recent reports from the AFL using similar methods,[8–10] and less than the earlier study that used video analysis.[1] The team investigated in this study was consistently ranked in the lower half of the competition during the period of this investigation; this poor team performance may explain the increased physical activity profile compared to the rest of the competition. It has recently been shown that players from less successful soccer teams in the Italian Serie A complete higher activity levels than their more successful counterparts, but spend less time in possession of the ball and are less efficient at some technical skills.[15] Future studies should examine if these relationships exist in the AFL.

The physical activity profiles observed from the players in this study demonstrates that AF players spend less time at higher intensities but are able to maintain the average speed in the higher zones as a match progresses (with the exception of peak speed in the fourth quarter). We also observed that the mean speed in lower speed zones decreased after the first quarter. It is possible that players adopt a subconscious pacing strategy by reducing efforts at lower speeds to permit the ability to achieve high speeds when required as the game proceeds.[18] These results agree with Duffield et al.,[3] who showed that during preseason matches in warm environmental conditions, elite-level AF players alter their physical activity profiles by reducing velocities at moderate and lower speed zones and maintaining the ability to exercise at higher intensities. Edwards and Noakes[19] also suggested that players might alter their behaviour (physical activity) during competitive, prolonged, high-intensity, intermittent exercise (soccer) on the basis of both pre-match contexts (e.g. prior experience in similar circumstances, fitness levels, match importance) and physiological alterations during the game (internal temperature, muscle metabolite accumulation, and substrate availability). This theory could explain the variations in time-motion profile during high-level AF matches. The role that regular player interchange or other breaks in play has in influencing player pacing strategy should be examined by future studies.

It is generally accepted that fatigue causes a reduction in exercise intensity during sports that require prolonged, high-intensity intermittent exercise.[3,20,21] Similar to these previous studies, TD, HIR and LIA were reduced in the fourth quarter, suggesting high levels of fatigue. The physiological cause of fatigue and the reduction in exercise intensity toward the end of each half and in the final quarter may be related to combined alterations in a number of metabolic systems. Factors such as inadequate resynthesis of ATP and phosphocreatine, accumulated muscle lactate, lowered muscle pH, carbohydrate depletion in some muscle fibres, dehydration, interstitial potassium accumulation, elevated core temperatures and central fatigue might underlie the reduced exercise intensity observed in this study.[22] However, the influence of team tactics and opponent activity levels cannot be discounted as other potential influences.[13]

In agreement with recent research in top-level soccer[13,14,23] and rugby league,[21] the results show that higher exercise intensity during each half or quarter in AF affects subsequent running performance in the next half or quarter of match play. Indeed, the present results demonstrate that for the players that exercised at a higher

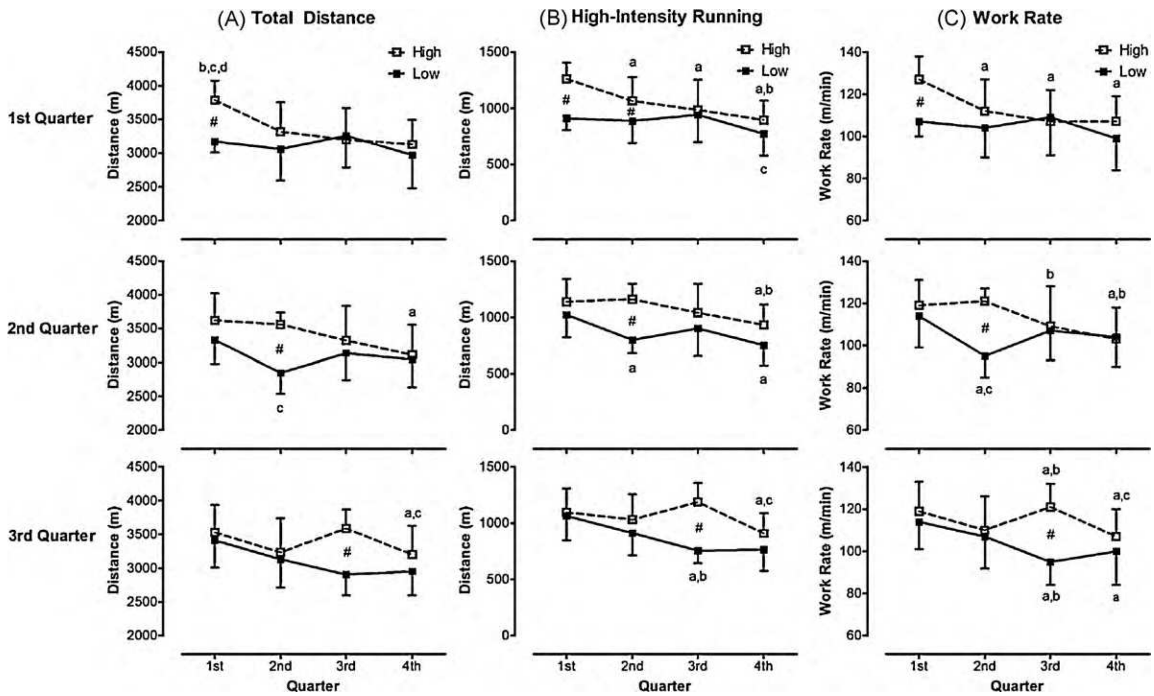

Fig. 2. Effect of increased (A) total distance, (B) high-intensity running (HIR); and (C) average speed on physical activity in subsequent quarters (mean ± SD). Median split groups into: High (□), players that travelled above the median value for the pooled data ($N = 32$); Low (■), players that travelled below the median value for the pooled data ($N = 32$). The median split made on data for the first, second and third quarters for each variable. Interactions were significant for all variables ($p < 0.001$). [#]Significantly different between High and Low group ($p < 0.05$), [a]significantly different to first quarter, [b]significantly different to second quarter ($p < 0.05$), [c]significantly different to third quarter ($p < 0.05$), and [d]significantly different to fourth quarter (all $p < 0.05$).

intensity in the first half, the physical performance indicators of TD, HIR and LIA were all decreased in the second half. In contrast, when players competed at lower exercise intensity during the first half, TD and average speed did not change significantly. Similar effects were observed between the high and low groups with the quarter by quarter analysis. In agreement with other research,[13] we observed that the group that exercised at a higher intensity during the first half of the match or quarter also travelled greater distance at higher intensities in the subsequent quarters of football. This could also be due to several factors such as positional roles or fitness. Regardless, these results have practical implications for coaches deciding when to make player interchanges and which player to interchange, particularly towards the end of the game. With the recent introduction of real-time monitoring of exercise in AF games at the elite level[24] this information could provide some basis for making decisions on player interchange.

It seems that the technical, tactical and physical activity profiles during match play are inextricably linked in the football codes.[13,15,21] A limitation of this study is that technical skill efficiency and the tactical approach of the team analysed could not be controlled for. Future studies should examine the complex relationships between these factors so that the relationships of physical activity profiles to overall AF performance are better understood. Indeed, the relationships between positional role, skill proficiency, physical activity and team success in AF require further investigation.

In summary, the present results show that higher exercise intensity during the early periods of AFL matches may influence the onset of fatigue towards the end of the match. The first quarter of match play is the most intense, and there was a reduction in TD and HIR travelled after the first quarter. The mean speed travelled during LIA was reduced following the first quarter, and this might have assisted the players to maintain intensities in HIR during the latter part of the game. Our results also showed that the decrement in TD and HIR during different periods in AF is not a systematic phenomenon but is associated with the amount of recent activity. We suggest that these results be used to better understand that factors associated with fatigue and variations of physical activity levels during elite-level AF.

5. Practical implications

- Coaches should be aware that players who exercise at higher intensity during a quarter have greater reduction in exercise intensity during the next quarter.
- Coaches may include real-time exercise intensity measures in Australian Football matches when making decisions regarding future player rotations.

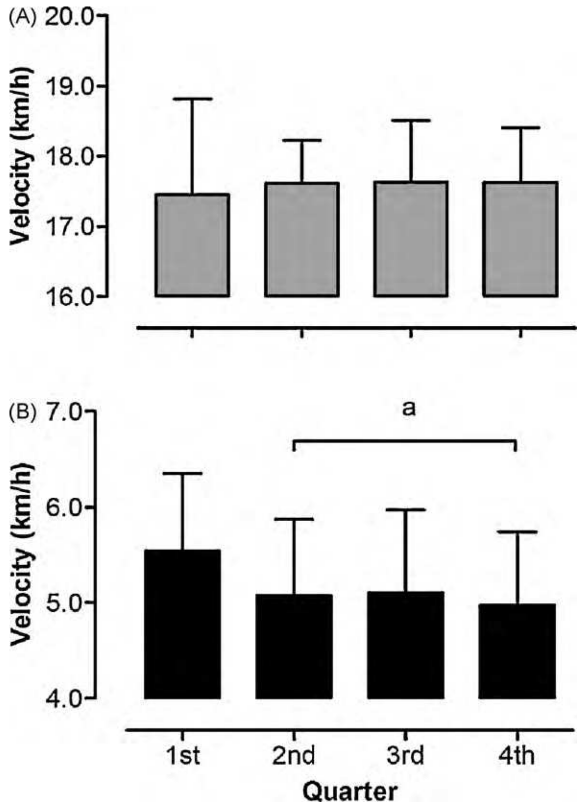

Fig. 3. Mean (±SD) speed for (A) high-intensity running (HIR); and (B) low-intensity activity (LIA) during four quarters of elite-level Australian Rules Football ($N = 65$). [a]Significantly different to first quarter.

- Coaches and sport scientists can use the information in this study to assist in designing and monitoring training drills that are specific to the physical demands of professional Australian Football.

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