NOVA
University of Newcastle Research Online
nova.newcastle.edu.au


As accepted for publication.

Accessed from: http://hdl.handle.net/1959.13/1053416
Title: The match demands of Australian Rules football umpires in a state-based competition.

Running Title: Physiology of Australian Football umpires.

Authors: Elsworthy, N.¹, and Dascombe, B.J.¹

Affiliations
¹ Exercise and Sport Science
Faculty of Science and Information Technology
University of Newcastle
Ourimbah, NSW 2258

Address for Correspondence
Dr Ben Dascombe
School of Environmental and Life Sciences
Faculty of Science and Information Technology
University of Newcastle
Ourimbah, NSW 2258
Ph: +61 2 4348 4150
Fax: +61 2 4349 4404
Email: Ben.Dascombe@newcastle.edu.au

Paper Type: Original Investigation
Abstract Word Count: 248
Word Count: 3,710
Number of References: 15
Number of Table: 2
Number of Figures: 1
Submission Date: 26 November 2015
**TITLE:** The match demands of Australian Rules football umpires in a state-based competition

**ABSTRACT**

_Purpose:_ The main purpose of the present study was to quantify the match running demands and physiological intensities of AF field and boundary umpires during match play. _Methods:_ Thirty-five AF umpires [20 field (age: 24.7 ± 7.7 yr, body mass: 74.3 ± 7.1 kg, Σ7 skinfolds: 67.8 ± 18.8 mm); 15 boundary (age: 29.6 ± 13.6 yr, body mass: 71.9 ± 3.1 kg, Σ7 skinfolds: 65.6 ± 8.8 mm)] volunteered to participate in the study. Movement characteristics [total distance (TD), average running speed, high-intensity activity (HIA; >14.4km·h⁻¹) distance] and physiological measures [heart rate, blood lactate concentration ([BLa⁻]), and rating of perceived exertion] were collected during 20 state-based AF matches. _Results:_ The mean (± SD) TD covered by field umpires was 11,492 ± 1,729 m, with boundary umpires covering 15,061 ± 1,749 m. The average running speed in field umpires was 103 ± 14 m·min⁻¹, and was 134 ± 14 m·min⁻¹ in boundary umpires. Field and boundary umpires covered 3,095 ± 752 m and 5,875 ± 1,590 m, during HIA, respectively. In the first quarter, HIA distance (field: p=0.004, η²=0.071, boundary: p<0.001, η²=0.180) and average running speed (field: p=0.002, η²=0.078, boundary: p<0.001, η²=0.191) were significantly greater than in subsequent quarters. _Conclusions:_ The results demonstrate that both AF field and boundary umpires complete similar running demands to elite AF players and are subject to physical fatigue. Further research is warranted to see if this physical fatigue impacts on the cognitive function of AF umpires during match play.

**Keywords:** Sport physiology; sport; physical performance
INTRODUCTION

The running performance of AF players has been widely examined in recent years.\textsuperscript{1-3} These existing studies have reported that elite AF players cover between 10,000-13,000 m during a match, at an average running speed of 110-125 m·min\textsuperscript{-1}.\textsuperscript{2,3} This relates to an average total distance (TD) of 2,800-3,500 m during each 20 min quarter of a match, of which 850-1,000 m is covered through high-intensity activity (HIA: >14.4 km·h\textsuperscript{-1}). Various studies have reported that the running demands of the first quarter are greater than subsequent quarters, suggesting a fatigue-related reduction in playing intensity.\textsuperscript{2,4} Similar declines have also been reported in important performance measures such as TD, HIA, and average running speed.\textsuperscript{2-5} Blood lactate concentrations ([BL\textsubscript{A}]) in AF players has been examined in one study.\textsuperscript{5} This study reported that during the fourth quarter, [BL\textsubscript{A}] was reduced when compared to the first, second and third quarters, however, these differences were not significant. Taken together, the physical and physiological data from players suggest that AF is best described as prolonged high-intensity intermittent exercise. Variations in running performance across a match may be a result of fatigue related mechanisms, as well as other factors including a slowing in the tempo of the match, a reduction of overall match intensity and increases in perceived effort.

Whilst the match running demands of players have been well documented (for a review see Gray and Jenkins, 2010),\textsuperscript{6} little peer-reviewed data is available detailing the match running demands and physiological intensities of AF umpires.\textsuperscript{7} Coutts and Reaburn\textsuperscript{7} completed a time motion analysis study on AF field umpires officiating national league games during the 1996 season using video-tracking methodology. The researchers reported that AF field umpires covered 10,563 ± 686 m during a match, with 41.2 ± 1.9% of this covered through backward running. At present, this is the only peer-reviewed research currently available quantifying the running demands of AF umpires. However, it can be suggested that the match demands of elite AF umpires has evolved significantly in the last 15 years in a similar manner to the varied demands of players over recent years due to changing structure and speed of the game.\textsuperscript{4,6} Additionally, the match running demands of AF boundary umpires has yet to be reported in peer-reviewed research.

In order to develop specific training and testing protocols for all umpiring disciplines, an updated assessment of the movement demands is necessary to quantify the current match demands. Furthermore, the magnitude of fatigue in AF umpires remains largely unknown, and this may play a significant role in the capacity to accurately make decisions towards the end of a match. The data may also help quantify the magnitude of physical fatigue experienced during a match, defined as a reduction in the high-intensity running. Therefore, the main purpose of the present study was to quantify the match running demands and physiological intensities of AF field and boundary umpires during match play.

METHODS

Thirty-five (n=35) male umpires from the premier division of the Sydney AFL competition volunteered to participate in the current study. The research group consisted of both field (n=20; age: 24.7 ± 7.7 yr, body mass: 74.3 ± 7.1 kg, Σ7 skinfolds: 67.8 ± 18.8 mm) and boundary (n=15; age: 29.6 ± 13.6 yr, body mass: 71.9 ± 3.1 kg, Σ7 skinfolds: 65.6 ± 8.8 mm) umpires. Subjects were screened for medical contraindications and provided informed consent prior to participation. Skinfold measure included a seven site skinfold assessment as an estimation of body fat percentage.\textsuperscript{8} The study and its methods were approved by the University of Newcastle Human Ethics Committee and supported by the Sydney AFL. Data was collected from 20 matches across the 2010 Sydney AFL season. Five umpires (three
field, two boundary umpires) were analysed across each match. A total of 97 data files were used for analysis (field umpires: n=60; boundary umpires: n=37).

During all matches, participants wore a Minimaxx global positioning system (GPS) device (Firmware v6.59; Catapult Innovations, Scoresby, Australia). Each device was fitted into an undergarment located between the scapulae and worn underneath their normal umpiring uniform. The GPS devices recorded latitude and longitude at a frequency of 5 Hz for the duration of the match. The units were turned on 20 minutes prior to play and then fitted to the participants 5 minutes before the scheduled match start time. Following each match, data was downloaded to a personal computer using Logan Plus software (v 4.4.0, Catapult Innovations, Scoresby, Australia). Each file from the match was manually divided into the four quarters and all non-playing data (quarter breaks) was removed. This data was transferred into a Microsoft Excel (Microsoft Corporation™, Redmond, Washington, USA) spreadsheet for data storage and analysis. Erroneous data was removed when a horizontal dilution of position value of greater than 5 was indicated, or when the number of connected satellites was less than 5.

**Game movements:** Data collected from the GPS units was separated into six velocity bands to calculate the distance covered and time spent at different intensities. These bands were categorised as: standing (<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); sprinting (>23 km·h⁻¹).²,⁹,¹⁰

**Match distances:** The distance covered in low intensity activity (LIA: <14.4 km·h⁻¹) and HIA (>14.4 km·h⁻¹) were calculated in addition to the total distance covered during each quarter. The number of HIA efforts were recorded as well as the average running speed maintained during each quarter of a match. These zones are consistent with recently published time-motion analysis studies.²,⁹,¹⁰

Heart rate responses were recorded using a Polar Team² Pro heart rate monitor (Polar Electro, Kemble, Finland) sampling at 5 second intervals. Data was stored within the GPS monitors and downloaded concurrently with movement data into Logan Plus following each match. Mean HR (HRmean) of each quarter were calculated post-match. Blood lactate was sampled from a hyperaemic earlobe using a Lactate Scout Analyser (EKF Diagnostics, Magdeburg, Germany) at the conclusion of each quarter. A 5 μl sample was drawn from each umpire within 1-2 minutes of the end of each quarter and immediately analysed. Participants were also required to rate their perceived exertion (RPE) at the conclusion of each quarter using the CR-10 scale. This was collected 3-5 minutes following the conclusion of each quarter.

**Statistical analysis:** All data are presented as the mean ± standard deviation (SD). Analysis was performed using PASW (v18.0, SPSS Inc., Chicago, Illinois, USA) statistics package and prior to the statistical test procedures normality and sphericity was assumed. Statistical significance was set at p<0.05. Data were divided according to umpiring discipline (i.e. field or boundary) and identical analyses were performed on each discipline.

A one-way analysis of variance (ANOVA) for repeated measures was used to determine the differences in match running performance between the four quarters. Game movements, match distances, number of efforts and other match performance measures were analysed. Where significant differences were found, a Bonferroni post-hoc comparison test was used. To control the Type-I error, an operational alpha level of 0.008 (p<0.05/6) was used for F values. Heart rate responses (HRmean), RPE and [BLa⁻] measurements over quarters were also
analysed. Cohen’s effect sizes ($\eta^2$) were used for these measures and values of 0.2, 0.5 and 0.8 were considered to represent small, medium and large differences, respectively.\textsuperscript{11}

A two-way mixed ANOVA (2x4 design) was used on each dependant variable to examine the effect of the amount of physical activity completed in one quarter (first, second or third quarter) on the physical performance measures in the following quarters. Using the median split technique, TD data were divided into two subsets, high or low, depending on TD covered in the reference period (i.e. first, second or third quarter). When a significant F value was found, Bonferroni post-hoc comparison tests were used. Average running speed, and HIA data was also analysed using the same techniques to examine the influence of these physical activity measures on the activity in the following quarter.

RESULTS

The mean TD covered by field umpires was 11,492 ± 1,729 m with boundary umpires covering 15,061 ± 1,749 m for an entire match. Tables 1 and 2 show the match running performance measures during each quarter of both field and boundary umpires, respectively. There were no significant variations in the TD covered during each quarter of a match, in either cohort. High-intensity activity accounted for 3,096 ± 752 m in field umpires and 5,876 ± 1,749 m in boundary umpires across a match. Significant declines were observed in HIA in both cohorts across the four quarters of a match (field: $p=0.004$; $\eta^2=0.071$; boundary: $p<0.001$; $\eta^2=0.180$). More specifically, a significant decline in HIA was observed between the first and fourth quarters in both the field (p=0.001) and boundary (p=0.001) umpires. The average running speed of field and boundary umpires was 103 ± 18 m·min\(^{-1}\) and 135 ± 14 m·min\(^{-1}\), respectively. A significant main effect of playing quarter was also reported for the average running speed in both umpiring cohorts (field: $p=0.002$; $\eta^2=0.078$; boundary: $p<0.001$; $\eta^2=0.191$). Post-hoc analysis revealed significant reductions in the average running speed during the fourth quarter in field umpires ($p=0.006$), and both the third ($p=0.002$) and fourth ($p=0.004$) quarters in boundary umpires when compared to the first.

**INSERT TABLE 1 AROUND HERE**

**INSERT TABLE 2 AROUND HERE**

Figure 1 (A) demonstrates the significant interaction in the TD, HIA distance and average running speed of field umpires during a quarter, and these measures in subsequent quarters. A significant effect (p=0.001, $\eta^2=0.171$) was demonstrated in the TD covered during the first quarter, and the running demands of subsequent quarters. As such, where a high TD was covered during the first quarter, the TD during the second, (p=0.020) and fourth (p=0.003) was significantly reduced. The HIA distance covered by field umpires significantly (p=0.001, $\eta^2=0.183$) influenced these demands during later quarters. More specifically, post-hoc analysis identified a significant reduction in HIA distance during the third (p=0.006) and fourth (p<0.001) quarters when a large HIA distance was covered during the first quarter. Furthermore, the average running speed of field umpires during the first quarter significantly (p<0.001, $\eta^2=0.265$) influenced the average running speed maintained in the second (p<0.001), third (p=0.001) and fourth (p<0.001) quarters.

Figure 1 (B) shows the interactions in the running performance measures of boundary umpires during a quarter, and these measures in subsequent quarters. Significant reductions (p=0.002, $\eta^2=0.244$) were observed in the TD during the third (p=0.004) and fourth (p=0.004) quarters, when a high TD was covered during the second quarter. A significant effect (p<0.001, $\eta^2=0.416$) was demonstrated in the HIA distance covered during the first quarter,
and the HIA distance covered in the remaining quarters. More specifically, when a large distance was covered in HIA during the first quarter, HIA distance during the second (p=0.004) and fourth (p≤0.000) quarters was significantly reduced. The average running speed of boundary umpires during the first quarter significantly (p=0.001, η²=0.289) influenced the average running speed during remaining quarters. As such, the average running speed in the third (p=0.001) and fourth (p=0.037) quarters was significantly reduced, when a high average running speed was maintained during the first quarter.

The physiological intensities of both field and boundary umpires are presented in Tables 1 and 2, respectively. Field umpires demonstrated a significant (p<0.001, η²=0.284) decline in [BLa\textsuperscript{−}] across the second (p<0.001), third (p<0.001), and fourth (p<0.001) quarters. There were no significant (p=0.302) reductions in [BLa\textsuperscript{−}] across a match in the boundary umpire cohort. Mean heart rate of field umpires showed a significant (p=0.003, η²=0.084) reduction across a match. During the third (p=0.010) and fourth (p=0.028) quarters, HR\text{mean} was significantly reduced compared to the second quarter in the field umpiring cohort. A significant main effect (p<0.001, η²=0.324) was identified in the HR\text{mean} of boundary umpires. More specifically, HR\text{mean} in the first quarter was significantly greater when compared to the third (p<0.001) and fourth (p=0.001) quarters. The RPE of field umpires showed a significant (p<0.001, η²=0.211) increase as a match progressed. During the third and fourth quarter, a significant increase in RPE was observed during the third (p=0.001) and fourth (p<0.001) quarters, compared to the first. There was no significant (p=0.084, η²=0.059) increase in the RPE of boundary umpires across a match.

DISCUSSION
The main purpose of the present study was to quantify the match running demands and physiological intensities of AF field and boundary umpires during match play. This study is the most comprehensive to quantify the match running demands of AF umpires across any level of competition. Additionally, it is the first to report upon the physiological intensities maintained by AF umpires across a match. The average running speed and HIA distance were greatest in the first quarter, with significant reductions observed in the subsequent quarters of both umpiring disciplines. The results of this study are similar to that reported for elite AF players, whereby the running performance decreased as a match progressed.\textsuperscript{2}

In addition to decline of running performance measures, reductions in physiological intensities (i.e. [BLa\textsuperscript{−}], HR\text{mean}) were also observed. An increase in the perceived effort for field umpires was found, however this remained constant in the boundary umpiring cohort as a match progressed. This supports the suggestion that AF umpires’ match performance may be influenced by fatigue. This may have major implications for both the physical and cognitive performance towards the end of matches as the umpires’ ability to obtain the correct position may be compromised, therefore leading to the possibility of decisional errors.\textsuperscript{12} Furthermore, the data showed that the running demands within a quarter, influence the match activities in subsequent quarters, thus may have implications for pacing strategies across a match.

The current results identified that the running demands of AF umpires are similar to that of elite AF players.\textsuperscript{1,3} The TD covered by field umpires in the current study was approximately 1,000 m less than that previously reported on AFL players.\textsuperscript{1,3} Separately, boundary umpires covered approximately 2,500 m more than AFL players. The only comprehensive peer-
reviewed research examining the running demands of AF umpires utilised simplistic video
analysis methodology and included small-subject numbers, so care must be taken when
interpreting and applying the results. However, this is the only previous data available on AF
field umpires, and the demands of the current study were considerably increased, most likely
reflecting the evolution of AF since 1996. The development of AF demands is supported by
the reported increases in various running performance measures (i.e. TD, HIA distance and
average running speed) of AF players between the 2005 and 2009 AFL seasons. This helps
to explain the increased running demands of field umpires between the current study and the
data of Coutts and Reaburn (2000). To date, no peer-reviewed research has examined the
running demands and physiological responses of AF boundary umpires.

The average running speed of the AF field and boundary umpires was significantly reduced
in the fourth quarter when compared to the first quarter. This may explain the similar decline
in the running demands of AF umpires compared to that reported in players. Previous
research demonstrated that players significantly reduce their average running speed across a
match, which suggests that their physical performance abilities was reduced. The current data
helps hypothesise that AF umpires may alter their running patterns or anticipation of play,
which could influence their average running speed across a match.

Significant decreases were also reported in the HIA distance between the first and fourth
quarters in both umpiring disciplines. These results suggest that a higher intensity of play is
maintained during the earlier periods of matches, and the requirement or capacity to complete
HIA declines during the latter periods of play. This supports previous data on AF players,
and suggests that the umpires have a reduced ability to complete HIA towards the end of
matches. Conversely, this observation may reflect the accumulative physical fatigue of AF
umpiring or alternatively, the reported reduction in the match demands due to players
reducing their HIA movements. This accumulation of fatigue in players would most likely
impact on the speed at which the umpires need to move to position themselves correctly to
adjudicate; though it is also likely that players increase the number of errors or infringements,
which would subsequently require the AF umpires to become more involved in the game.
However, further analysis of positioning, accuracy of decision making and running demands
in AF umpires is required.

The significant reduction in [BLa−] during the match in the AF field umpires suggests a
greater contribution of energy from anaerobic metabolism in the early stages of a match. This
would most likely reduce the availability of substrates required for anaerobic glycolysis in the
latter stages of a match, and resultantly reduce the capacity to perform HIA towards the end
of a match. However, the reduced [BLa−] in the AF field umpires may also have been due to
a global reduction of game intensity, which could lead to a reduction in the frequency of HIA.
The available RPE data suggests that the AF field umpires has a higher perception of effort in
the latter in the stages of a match, due to stable RPE measures and decreases in running
performance measures (i.e. HIA and average running speed). These factors help suggest that
AF field umpires perceive themselves to fatigue as identified by a reduction in running
performance measures and an increase in their RPE measures. Boundary umpires displayed a
similar trend in their perceived magnitude of fatigue; though they didn’t demonstrate the
significant increase in RPE. These results demonstrate that in addition to the physical fatigue
identified through the reductions in measures of running performance, the AF umpires
maintained or increased their perception of effort, which is further indicative that AF umpires
are subject to fatigue across a match.
During high-intensity intermittent exercise, such as Af, it is common for work intensities to decline as a result of the onset of fatigue.\textsuperscript{1,2} Previously, it has been reported that fatigue in high-intensity intermittent exercise is multifactorial, with possible causal mechanisms including glycogen depletion, dehydration, potassium accumulation, muscle H\textsuperscript{+} increase and muscle lactate accumulation.\textsuperscript{13} These factors may inhibit the umpires’ ability to maintain performance over an entire match, with a particular focus on the positioning requirements.

Throughout a match, the umpire is required to keep up with play and move quickly into positions that provide them with the best vantage point to make a judgement on the play. A reduction in the HIA and average running speed suggests that the ability to complete HIA may be reduced.\textsuperscript{13} Therefore, this may inhibit the umpires match performance, particularly during the latter stages of a match. In further support, the running demands within a quarter appears to be somewhat influenced by the imposed demands in previous quarters of a match. The results suggest that field umpires that completed greater running demands (i.e. large TD, large HIA distance or high average running speed) in an early quarter compared to the group median (Figure 1), commonly displayed a significant reduction in these measures in subsequent quarters. Similar results were also reported in AF boundary umpires. These results support previous research reporting similar trends in elite AF players.\textsuperscript{2} This strengthens the suggestion that there are a number of factors including a decrease in overall match intensity, fatigue mechanisms or an increased perceived effort may influence the physical performance of AF umpires and players across the four quarters of a match. It might be suggested that umpires that have a high workload in a quarter may have impaired physical capacity in subsequent quarters.

Currently, it is perceived that the three-umpire system requires the field umpire located in the mid-zone of the field, to complete a greater amount of HIA than those field umpires in other areas of the field. This is due to the greater ground area controlled by the mid-zone umpire and play remains in this portion of the ground for a greater amount of time. On-field rotations by the officiating field umpires may allow the workload for a match to be shared equally amongst the field umpires. While this analysis is outside the scope of the current study, future research should attempt to differentiate the specific demands of different AF umpiring positions, and determine strategies to quantify where the majority of high-intensity activity is performed.

Some limitations existed in the current research project. The standard of competition was not elite AFL level, and comparisons made to previous research may be influenced by differences of sub-elite and elite players.\textsuperscript{14} Additionally, backward running provides a major proportion of the running demands in AF field and boundary umpires. However, due to technological limitations of the GPS units this was unable to be quantified. Future studies should quantify the proportion of match demands that backward running currently consists of given that it incurs a greater physiological cost.\textsuperscript{15}

CONCLUSION

In summary, the results of the present study detailed that the match running demands of AF field and boundary umpires, and found them to be similar to elite AF players. Of interest, the TD, HIA distance and average running speed of both field and boundary umpires were most demanding in the first quarter, with significant declines observed in the latter quarters of a match, suggesting that physical and physiological fatigue was present. It is likely that this fatigue will reduce the ability of the AF umpire to move into the best vantage point to adjudicate on play and improve the likelihood of correct ruling. Future studies should
examine the relationship between the match running demands and cognitive function capacity that are specific to AF umpires and other team sport officials.

PRACTICAL IMPLICATIONS

- The reported match running demands of AF umpires can be used in the development specific training and testing protocols for the umpiring disciplines.
- The data suggests that AF umpires fatigue across the latter stages of a match. Future work should utilise interventionist strategies to minimise its effects.
- Umpire coaches can now monitor the running demands of field and boundary umpires as measures of AF umpire performance.

ACKNOWLEDGEMENT

There was no outside financial assistance for the current project. The researchers would like to express their gratitude to the Sydney AFL umpiring group, in particular Mr Graham Glassford for their support. Additionally, Mr Tim Knight must be thanked for his valuable assistance with the data collection.
REFERENCES

FIGURE CAPTIONS

Table 1: Measures of match running performance of AF field umpires (n=60 files) during each quarter (mean ± SD).

Table 2: Measures of match running performance of AF boundary umpires (n=37 files) during each quarter (mean ± SD).

Figure 1: Effect of total distance, high-intensity activity and average speed on physical activity of (A) field umpires and (B) boundary umpires in following quarters (mean ± SD).