Possession Chain Factors and Player Skill Involvements Influence Movement Demands in Elite Australian Football Match-play

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Statement of Authorship

I, Andrew Vella, declare that this thesis entitled "Possession Chain Factors and Player Skill Involvements Influence Movement Demands in Elite Australian Football Match-play" includes work by the author that has been published or accepted for publication as described in the text. Except where references are made in the text of the thesis, this thesis contains no other material published elsewhere or extracted in whole or in part from a thesis accepted for the award of any other degree or diploma. No other person's work has been used without due acknowledgment in the main text of the thesis. This thesis has not been submitted for the award of any degree or diploma in any other tertiary institution.

Signed

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Date

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Abstract

Match physical activity characteristics in Australian Football (AF) have historically been described using whole of match, half or quarter measures. While this has provided broad information on the activity demands of AF match-play, it does not provide specific information as to how the game is played or analysed by coaches (i.e. in phases of play or possession chains). Additionally, knowledge of the context in which activity demands occurs remains scarce. This thesis examined the influence that contextual factors and events occuring during individual possession chains had on the activity demands of professional AF players. Study One examined the influence that field position, initial chain state, and possession phase had on match movement demands. Compared to when players cover the full distance of the ground, total distance (TD) and high-speed running (HSR) distances were lower when attacking chains initiated from the forward 50-m arc and attacking midfield, or when defensive chains initiated from the defensive 50-m arc and defensive midfield ($p \leq 0.001$). Furthermore, TD and HSR outputs were greatest when possession chains initiated from a kick-in or intercept, compared to a stoppage ($p \leq 0.001$). Study Two extended study one by looking at initial chain state, field territory gained and possession phase in addition to technical contextual factors such as player involvement and pressure of the observation and opposition players. Field territory gained, and chains initiated from kick-ins or turnovers increased player activity for TD and HSR during all possession phases ($p \leq 0.001$). During attacking chains, TD and HSR were greatest when individual players were directly involved in a chain, whereas when the total number of players involved in a chain increased, activity demands were reduced ($p \leq 0.001$). During defensive chains TD and HSR demands increased when players applied pressure on the opposition, however, were reduced when more opposition players touched the ball ($p \leq 0.001$). Overall, this thesis confirmed that activity demands increased when play initiated from field positions furthest from a team’s goal, kick-ins or turnovers, and when individual players were directly involved in the play. This is important in understanding the technical involvements and in-game contextual factors that influence the activity demands of AF players. Subsequently, this information could be used by coaches and practitioners in designing training drills more representative of realistic match conditions, or inform tactical strategies to be used during match-play.

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List of Abbreviations

AF	Australian Football
AFL	Australian Football League
CI	Confidence intervals
CL	Confidence limits
CNA	Complex Network Analysis
ES	Effect size
GPS	Global Positioning System
HSR	High-speed running
LPS	Local Positioning System
m	Metre
MID	Midfielder
NR	Not reported
PRISMA	Preferred Resting Items of Systematic Reviews and Meta-Analysis
SD	Standard deviation
SNA	Social Network Analysis
TD	Total distance

Chapter One

Introduction

1.1 Background

Most Australian Football (AF) match analysis studies have reported whole or quarter-by-quarter physical activity information (Brewer et al., 2010; Coutts et al., 2010). These studies have enhanced our understanding of the activity demands during AF match-play, subsequently informing training prescription. However, these studies potentially neglect peak demands of match-play and therefore underestimate the activity demands of AF competition. As such, recent research has examined activity demands during peak periods of play using arbitrary rolling time periods (Black et al., 2016; Delaney et al., 2017; Johnston et al., 2019). Peak periods of play have been associated with the most critical moments in match-play (Delaney et al., 2017). By understanding the activity demands during these moments of play, player preparedness can be enhanced through the modification of athlete physical preparation programs to account for peak period requirements. Overall, these studies provide important information regarding peak demands of match-play, adding further specificity to training drill design and prescription (Black et al., 2016; Delaney et al., 2017; Johnston et al., 2019). However, AF requires a unique combination of physical, technical, and tactical proficiencies for high-level competition performance (Sullivan et al., 2014a). Therefore, investigation of how in-game contextual factors and player skill involvements influence activity demands during different phases of play is required. This will provide an understanding of the physical requirements associated with various tactical strategies and player involvements during attacking, defensive, and contested phases of play.

Technical proficiency is an important component to both individual and team performances in AF (Robertson et al., 2016a). Studies investigating the technical demands of AF match-play have typically analysed discrete actions by both players and teams. Using notational analysis and data collected by Champion Data – the Australian Football League's (AFL) statistical provider – studies have been able to detail the frequency of skill-based match events such as kicks, marks and handballs (Ireland et al., 2019; Kempton et al., 2015) as well as create models to predict match outcome (Robertson et al., 2016a; Young et al., 2019b; Young et al., 2019c). These studies collectively provide important information on the technical demands of AF match-play and the technical characteristics of successful performances in AF. However, a common limitation to these studies is that they often isolate and compare physical and technical data sources as opposed to integrating them and reporting their relationship to one another. At present, little is known about the possible association between specific skill measures (player involvement and defensive pressure) and the activity demands of players during attacking and defensive phases of play. Such knowledge may enhance our understanding of the relationship between technical skill involvements and the physical output of players, as well as provide new information on applying pressure to the opposition from an individual and team perspective.

Recently, studies have investigated the tactical strategies of teams by measuring the interactions amongst team-mates and the collective positioning of players during competitive matches, gaining insights into team tactics associated with match performance. The use of network analysis has become increasingly popular in AF and has provided insights into the efficiency and functionality of a team's passing networks, and the passing measures associated to match outcome (Braham and Small, 2018; Taylor et al., 2020; Young et al., 2020). Spatiotemporal data on player positioning has extended the knowledge of tactical strategies in the AFL by measuring the collective behaviours of players during various phases of match-play (Alexander et al., 2019). This data assists practitioners in understanding the various tactics teams employ, helping to both exploit the opposition during match-play and reinforce desired positioning of players during specific training drills. However, team tactics are altered dependant on the field location and the initial chain state (i.e. kick-in, turnover, or stoppage), which subsequently influence the activity demands of players. Therefore, investigation of the relationship between field location, initial chain state and the activity demands of players during different phases of play is warranted. This will extend on previous research and provide new information on individual and collective team behaviours during various tactical strategies.

1.2 Statement of the Problem

While previous research has provided important information on the physical, technical and tactical constructs of AF match-play, studies often analyse these entities in isolation. This is not reflective of the context in which they occur during match-play and as such limits the findings of previous research. Furthermore, coaches analyse the game through individual possession chains (plays that are controlled by a singular team) and examine the technical proficiency, tactical execution and physical activity of players as a whole. This highlights a disconnection between current sports science and coaching match analysis practices. As such, the application of movement data for coaches becomes limited when designing training drills and interpreting player movement patterns during match-play.

1.3 Thesis Aims

This thesis aimed to break down match-play into individual possession chains to get a more granular understanding of the physical activity characteristics of AF match-play. Study one examined the influence that possession phase, starting field position, and initial chain state (kick-in, intercept or stoppage) had on the activity demands of professional AF players. This study aimed to provide knowledge of the activity demands associated with various tactical strategies. Study two examined the influence that possession phase, initial chain state, chain distance, and technical skill involvements (player involvement and pressure applied) of the observed team and opposition had on the activity demands of pressional AF players. This study built upon the findings of study one by providing knowledge of the activity demands associated with various tactical strategies and the technical skill involvements occuring within these chains.

Chapter Two

Literature Review

2.1 Introduction

Australian Football (AF) is a contact field-based sport characterised by intermittent locomotive demands, where bouts of high intensity running activity (running, accelerating, and sprinting) are interspersed with prolonged low intensity activity (walking or jogging) (Gray and Jenkins, 2010; Sargent and Bedford, 2013). The game is contested between two teams of 18 players, with four players available for interchange, with a maximum of 90 rotations permitted per team throughout the match (Sargent and Bedford, 2013). Competition matches are divided into four 20-min quarters (plus added time for stoppages), separated by two 6-min quarter breaks and a 20-min half time break (Johnston et al., 2018). The objective of the game is to outscore your opponent, which is facilitated by advancing the ball via kicks, handballs, spoils, and taps to a scoring position (Gray and Jenkins, 2010; Johnston et al., 2018; Sargent and Bedford, 2013). The premier competition is the Australian Football League (AFL) where 18 teams play 22 home-and-away matches followed by a four-week finals series for the eight top-ranked teams to determine the premiership (Johnston et al., 2018). Currently, there are thought to be three key constructs that encompass match-play in AF. They are: physical (e.g., running, accelerating, walking) (Bauer et al., 2015; Coutts et al., 2015), technical (e.g., kicking, handballing, tackling) (Ireland et al., 2019; Sullivan et al., 2014b) and tactical (e.g., collective team behaviour, ball movement) (Woods et al., 2017; Young et al., 2020). Although these have been studied as separate entities, the reality of them occurring individually during competition is scarce. Therefore, it has been encouraged that practitioners integrate data sources of each construct so that when analysed, the data accurately reflects the context in which they occur.

Advancements in technology have led to Global Positioning Systems (GPS) in sports becoming prominent, allowing practitioners to quantify the external workload completed by athletes. Prior to the turn of the century, Schutz and Chambaz (1997) pioneered the use of GPS in athletic tracking, however, it was not until 2005 that the AFL adopted the microtechnology (Gray and Jenkins, 2010; Wisbey, 2008). In contemporary AFL, it is mandatory that all players wear GPS units during all formal matches and training sessions. This provides sports scientist with real-time and post-hoc information on the external load completed by players, subsequently informing future training prescription (Burgess et al., 2012). GPS are typically identified by their sample rate (expressed in Hertz) at which the chipset and satellite communicate per second to determine the devices location. Initial devices sampled at a rate of 1Hz (one sample per second), however, with advancements in technology commercially available GPS units now come with sample rates of 5 Hz, 10 Hz or 15 Hz (Johnston et al., 2018). These devices have enabled the quantification of player activity demands (i.e. distance, running velocities, and peak movement demands) during match-play, with the information then being used to guide training prescription (Cummins et al., 2013). While most research observing match activity is with the intention to improve training prescription (Brewer et al., 2010; Coutts et al., 2015), other research is starting to explore the link between physical movements and match outcomes at a team level (Mooney et al., 2011; Sullivan et al., 2014a), and the link between physical movements and technical involvements during match-play (Johnston et al., 2019).

Skill execution is an important contributor to individual and team performance in AF (Robertson et al., 2016b; Sullivan et al., 2014a), and can be assessed via technical aspects of competition such as the number and efficiency of key technical actions (e.g. kicks, handballs, and marks). These match events are collected by a statistics provider to the AFL (Champion Data Pty Ltd, Melbourne, VIC), and the information is used to understand match activities and also in the design of training drills that resemble specific match conditions (Corbett et al., 2018; Parrington et al., 2013). While an abundance of information exists regarding technical demands during AF match-play, there is a dearth of information regarding skill-based match events that influence match activity demands (Robertson et al., 2016a; Sullivan et al., 2014a; Young et al., 2020). Research that has combined both physical and technical measures of AF match-play centre around how both constructs influence individual and team base performances (Dillon et al., 2018; Sullivan et al., 2014a). These studies provide an understanding of how subjective and objective measures of performance are favoured towards technical skill-based measures, however, in regards to how these two constructs interact to one another, evidence is limited. By quantifying the influence that technical skill involvements have on the activity demands of AF athletes, coaches can begin to implement training drills that replicate the demands of match-play, serving to not only refine the players technical proficiency but to additionally refine the skills necessary to both practice and implement specific tactical plays/styles.

Given the complexity of performance within team sports, understanding the tactical behaviours and interactions (i.e. player positioning and passing networks) of a team is crucial to understand what comprises the activity demands of players during match-play. Without the context of the team, technical skill measures on their own are not enough to summarise the activity demands of athletes and gain meaningful information (Sargent and Bedford 2013; Vilar et al., 2012). Spatiotemporal data derived from GPS units and network analysis methods have therefore been employed to observe the interactions and positioning of players throughout a match, providing insights into the tactics of various teams. While most research using these techniques has been conducted with soccer (Bialkowski et al., 2014; Castello et al., 2013; Clemente et al., 2013), there has been a recent shift towards these analytical approaches in AF (Alexander et al., 2019; Sheehan et al., 2020b; Young et al., 2019a). With the similarity between AF and soccer – both being 360° games where players can pass in any direction – similar analysis methods may be useful in understanding the collective actions and interactions amongst teammates during AF match-play. This information about how the team or opposition's tactics influence player activity demands could subsequently be analysed by coaches with the intent of developing training drills representative of specific match scenarios. This would ensure players have the capabilities to execute the desired game plan under the stressors of AFL competition.

While the activity demands of AF match-play have been well documented, these analyses are often isolated from technical and tactical considerations, two important constructs of match-play (Impellizzeri et al., 2009). Given the multifactorial nature of AF, it is important to incorporate all three constructs (physical, technical and tactical) when trying to understand the activity demands of athletes during competitive matches. Therefore, further investigation of how all three constructs interact during match-play is warranted. The aims of this systematic review were to 1) provide an update of match activity demands primarily focused on the variables practitioners most commonly examine in AFL (i.e. absolute and relative distances for average, high speed, and peak demands); 2) detail the technical demands of AF match-play; 3) identify common tactical analysis methods of match-play, and, 4) detail how the three constructs (physical, technical and tactical) influence one another and the importance of integrated data analysis.

2.2 Methods

Design and search strategy

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Review and Meta-analysis) guidelines (Moher et al., 2009). A systematic search of the literature was conducted in various electronic databases: CINHAL, PubMed, Scopus, SPORTSDiscus, and Web of Science. Articles for this review were focused on peer-reviewed journals from January 2009 until August 2020. The start date was chosen based on when GPS became prominent in AFL and all teams were regularly using GPS to monitor player workloads (Wisbey et al., 2008). The combination of the terms listed in Table 2.1 were used to search and obtain the titles, abstracts and key words of articles within each database.

Table 2.1 Search terms used in each database. Searches 1 and 2 were combined with "AND".

Search 1	Search 2
"Australian Football" OR "Australian Football League" OR "Australian Rules Football"	"Match demands" OR "activity profiles" OR "running demands" OR "game demands" OR "running performance" OR "external load" OR "contextual factors" OR "movement patterns" OR "team behaviour" OR "skill" OR "technical" OR "match outcome"

Screening and study selection

All references obtained were imported into a reference manager application (Endnote X9, Thomas Reuters, Philadelphia, USA) where all duplicate articles were then eliminated (Figure 1). Articles were screened independently by two researchers (AV and TK) to decide which studies met the inclusion criteria determined by the title, abstract, or when required via full-text. The titles and authors were not masked to the reviewers.

Studies that assessed the physical (via GPS), technical, or tactical constructs of AFL competition were included in the review. The exclusion criteria of this review included any study that assessed musculoskeletal injuries or the psychological, sociological, or nutritional aspect of AFL. Likewise, any study examining the physical, technical or tactical demands of training, or any competition other than the AFL (e.g. youth, state league, or women's AF) were excluded. To avoid artificially high match running intensities, articles that reported data for athletes that played <70% game time were excluded from the review (Mooney et al., 2011).

Upon selecting the articles for inclusion, the reference list of each article was scanned for any potentially relevant studies that were not retrieved in the original search.

Data extraction

For all studies included in this systematic review, data characteristics (i.e. number of files/matches/players) and methods of data collection and analysis were extracted. Where studies included the use of GPS, data on GPS unit specifications (i.e. brand, model, sampling frequency, software) were also extracted. For the purpose of this review, reporting of GPS data was limited to total distance (TD) (m), relative distance ($m.min^{-1}$), high-speed running (HSR) distance (m), HSR relative distance ($HSm.min^{-1}$), peak relative distance ($m.min^{-1}$) and peak HSR relative distance ($HSm.min^{-1}$). All variables were converted to metres and metres per minute for ease of comparison, while HSR thresholds were converted to km/h. Where data was reported using a different unit of measure, conversion and/or calculation based on total match or active (on-field) playing time duration was completed where appropriate. For example, to calculate relative distance, TD was divided by total match duration in minutes. Additionally, mean and standard deviations (SD) that were presented in figures were extracted using an online extraction tool WebPlotDigitizer v4.2. Where studies examined the technical or tactical aspects of AFL, the data retrieval (i.e. Champion Data, broadcast vision) and analysis method (i.e. social network analysis, spatiotemporal data) were also extracted.

Assessment of methodological quality

The methodological quality of each study was assessed by two researchers using a modified version of a previously validated scale (Downs and Black, 1998). Certain criteria measures were not applicable to the studies in this review. Therefore, only 11 of the 27 criteria were used (1-3, 6, 7, 10-12, 16, 18, 20). This is a similar approach to other reviews within this field (Whitehead et al., 2018). Question 10 was modified to assess the inclusion of effect size reporting as opposed to probability values (i.e. *p*-values). Using the 11 criteria used in the assessment a score of ‘0’ represented if the item was absent or insufficiently detailed, while a score of ‘1’ represented if the item was explicitly detailed. Methodological quality scores ranged from excellent (10-11); good (8-9); fair (5-7); and poor (<5). No studies were omitted based on the methodological quality assessment criteria.

Statistical analysis

A meta-analysis was not performed as the wide variety of study designs and outcome variables meant studies could not be pooled. All data are presented as mean ± SD or as mean (confidence limits, CL) unless otherwise stated.

2.3 Results

Search results

The initial search returned 1193 articles from across five databases (CINAHL = 286, PubMed = 153, Scopus = 197, SPORTSDiscus = 256, Web of Science = 300), with one study added after being identified in the reference list of another article. Following the initial search, 713 articles were removed for being either a duplicate, book, video conference, or review article. The title and abstract of the remaining 480 articles were then screened where a following 383 were removed for not fitting the inclusion criteria. This resulted in 97 articles being screened via full text where a further 51 articles were excluded, resulting in 46 articles that met the inclusion criteria. The schematic process of articles that were potentially relevant for inclusion is displayed in Figure 2.1.

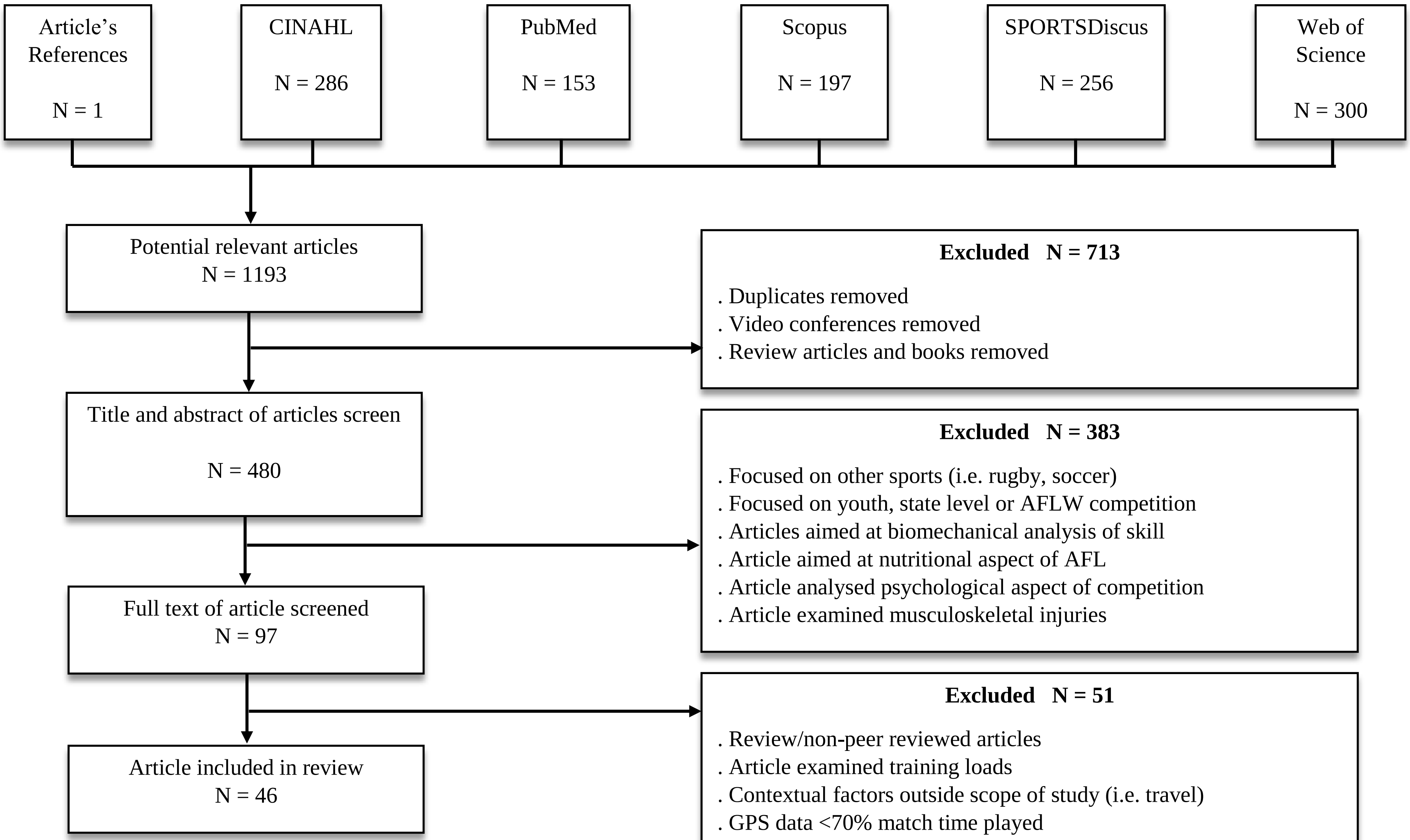

Figure 2.1 Study selection flow chart.

Methodological quality

The methodological quality assessment scores of each study are shown in Table 2.2. Scores ranged from seven to nine for the 11 items assessed. Of the 46 studies, 43% (n = 20) received a score of nine, 30% (n = 14) received a score of eight, 26% (n = 12) received a score of seven.

Study characteristics

Of the 46 studies included in this review, most studies looked at a single construct of AFL match performance (Table 2.2). In isolation, physical match demands were reported in 17 studies, technical demands in nine studies, and tactical demands in six studies. Thirteen studies reported both physical and technical variables, while one study observed technical and tactical constructs together. The data source and number of files used for each study are reported in Table 2.2. The majority of studies reporting on the activity demands of players were from a single team, while studies focusing on technical and tactical constructs were more likely to include larger datasets. Catapult devices (10 Hz) were the most common equipment used to collect GPS locomotive data, while skill-based match events were most commonly obtained from one commercial statistic provider (Champion Data Pty Ltd, Melbourne, VIC). Three different analysis methods were used to investigate tactical demands, including: social network analysis (n = 3 studies), complex networks (n = 3 studies) and spatiotemporal data (n = 1 study) (Table 2.2). Within locomotor AF studies, most studies (n = 25) reported the average whole match running demands, four studies included peak running demands and one reported on possession chain (passages of play that are controlled by a singular team) running demands. Five different HSR thresholds were utilised, while four studies did not report the specific HSR threshold used (Table 2.3).

Table 2.2 Characteristics of the studies in this review.

Study	Construct analysed	Analysis method	No. of matches	No. of files	No. of players	Methodological quality score
Alexander et al. (2019)	Tact	Spatiotemporal data	1	NR	22	8
Anderson et al. (2018)	Tech	BV	198	NR	NR	7
Aughey (2010)	Phys	GPS	29	147	18	9
Aughey (2011)	Phys	GPS	6	NR	8	9
Aughey (2013)	Phys	GPS	29	2,015	35	9
Bauer et al. (2015)	Phys & Tech	GPS & CD	11	204	35	9
Black et al. (2016)	Phys & Tech	GPS & BV	13	163	24	9
Braham & Small (2018)	Tact	CNA	207	NR	NR	7
Brewer et al. (2010)	Phys	GPS	NR	315	33	9
Corbett et al. (2017)	Phys	GPS & LPS	21	NR	39	8
Corbett et al. (2019)	Phys & Tech	GPS, LPS & CD	19	NR	37	8
Coutts et al. (2010)	Phys	GPS	25	79	16	8
Coutts et al. (2015)	Phys	GPS	19	342	39	9
Delaney et al. (2017)	Phys	GPS	30	623	40	9
Dillon et al. (2018)	Phys & Tech	GPS & CD	15	NR	33	9
Gronow et al. (2014)	Phys	GPS	14	NR	36	8
Hiscock et al. (2012)	Phys & Tech	GPS & CD	17	355	30	9
Ireland et al. (2019)	Tech	CD	16	NR	33	9
Johnston et al. (2012)	Phys & Tech	GPS & CD	12	69	21	9
Johnston et al. (2015)	Phys & Tech	GPS & CD	NR	230	21	9
Johnston et al. (2016)	Phys & Tech	GPS & CD	NR	336	19	9
Johnston et al. (2019)	Phys & Tech	GPS & CD	22	450	38	9
Kelly et al. (2019)	Phys	GPS & CD	NR	237	20	9
Kempton et al. (2015)	Phys	GPS & CD	31	511	33	8

Montgomery & Wisbey (2016)	Phys	GPS & CD	NR	7,730	21	9
Mooney et al. (2011)	Phys & Tech	GPS	5	NR	46	8
Mooney et al. (2013)	Phys	GPS	22	NR	15	8
Parrington et al. (2013)	Tech	BV	14	NR	NR	7
Rennie et al. (2020)	Phys & Tech	GPS & CD	18	360	33	9
Ritchie et al. (2016)	Phys	GPS	13	932	44	9
Robertson et al. (2016a)	Tech	CD	39	NR	NR	7
Robertson et al. (2016b)	Tech	CD	198	NR	NR	7
Ryan et al. (2017)	Phys	GPS	15	NR	34	9
Sargent & Bedford (2013)	Tact	SNA	25	NR	34	7
Sheehan et al. (2020b)	Tact	CNA	73	1,603	48	7
Sullivan et al. (2014a)	Phys & Tech	GPS & CD	15	292	40	8
Sullivan et al. (2014b)	Phys & Tech	GPS & CD	15	292	40	8
Taylor et al. (2020)	Tact	CD & CNA	194	1,720	665	8
Varley et al. (2014)	Phys	GPS	27	176	28	8
Wisbey et al. (2010)	Phys	GPS	NR	793	179	8
Woods. (2016)	Tech	CD	394	NR	NR	7
Woods et al. (2017)	Tech	CD	249	NR	NR	8
Young et al. (2019a)	Tact	SNA	1,516	3,032	NR	7
Young et al. (2019b)	Tech	CD	3,145	NR	NR	7
Young et al. (2019c)	Tech	CD	3,145	NR	NR	7
Young et al. (2020)	Tech & Tact	CD & SNA	1,516	3,032	NR	7

Phys = Physical; Tech = Technical; Tact = Tactical; GPS = Global Positioning System; LPS = Local Positioning System; BV = Broadcast vision; CD = Champion Data; SNA = social network analysis; CNA = complex network analysis; NR = not reported

Table 2.3 High-speed running thresholds and GPS hardware/software specifics utilised by studies in this review.

Study	Locomotive demands	Brand	Model	GPS sampling frequency (Hz)	Software	HSR threshold
Aughey (2010)	Global	Catapult	NR	5	Logan Plus v 4.1	>15 km/h
Aughey (2011)	Global	Catapult	NR	5	Logan Plus v 4.1	>15 km/h
Aughey (2013)	Global	Catapult	NR	5	Logan Plus v 4.2.3	>15 km/h
Bauer et al. (2015)	Global	Catapult	MinimaxX S4	10	Sprint v 5.0.9.2	>19.8 km/h
Black et al. (2016)	Peak	Catapult	MinimaxX S4	10	NR	>15 km/h
Brewer et al. (2010)	Global	GPSports	SPI 10	5	GPSports TAS v 1.6.2	>15 km/h
Corbett et al. (2017)	Global	Catapult	T5 (LPS) and S5	10	Openfield v 1.11.2 – 1.13.1	>14.4 km/h
Corbett et al.(2019)	Peak	Catapult	T5 (LPS) and S5	10	Openfield v 1.11.2 – 1.13.1	NR
Coutts et al. (2010)	Global	GPSports	SPI 10	1	GPSports TAS v 1.6.	>14.4 km/h
Coutts et al. (2015)	Global	Catapult	NR	10	Sprint v 5.0.6	>14.4 km/h
Delaney et al. (2017)	Peak	Catapult	MinimaxX S5	10	Openfield v 1.12.0	>19.8 km/h
Dillon et al. (2018)	Global	Catapult	Optimeye S5	10	Openfield v 1.11.1	>20 km/h
Gronow et al. (2014)	Global	GPSports	SPI Pro X	5	Team AMS-release	>14 km/h
Hiscock et al. (2012)	Global	GPSports	SPI Pro X	15	Team AMS-release	>14 km/h
Johnston et al. (2012)	Global	Catapult	NR	5	NR	>14 km/h
Johnston et al. (2015)	Global	Catapult	MinimaxX S3 & S4	5 and 10	Sprint v 5.0.9	>14.4 km/h
Johnston et al.(2016)	Global	Catapult	MinimaxX S3 & S4	5 and 10	Sprint v 5.0.9	>14.4 km/h

Johnston et al. (2019)	Peak	Catapult	Optimeye S5	10	Openfield v 1.15.0	NR
Kelly et al. (2019)	Global	Catapult	MinimaxX S4	10	Sprint v 5.1.6	>14 km/h
Kempton et al. (2015)	Global	Catapult	NR	10	Sprint v 5.0.6	>14.4 km/h
Montgomery and Wisbey (2016)	Global	Catapult	NR	10	NR	NR
Mooney et al. (2011)	Global	Catapult	NR	5	Logan Plus v 4.4.0	>15 km/h
Mooney et al. (2013)	Global	Catapult	NR	5	Logan Plus v 4.4.0	>15 km/h
Rennie et al. (2020)	PC	Catapult	Optimeye S5	10	Sprint v 5.1.7	>14.4 km/h
Ritchie et al. (2016)	Global	Catapult	MinimaxX S4	10	Sprint v 5.1.3	>14.4 km/h
Ryan et al. (2017)	Global	Catapult	Optimeye S5	10	Openfield v 1.12.2	>20 km/h
Sullivan et al. (2014a)	Global	Catapult	NR	10	Sprint v 5.0.6	>14.4 km/h
Sullivan et al. (2014b)	Global	Catapult	NR	10	Sprint v 5.0.6	>14.4 km/h
Varley et al. (2014)	Global	Catapult	NR	5	NR	>19.8 km/h
Wisbey et al. (2010)	Global	GPSports	SPI 10 and SPI Elite	1	NR	NR

Global = average demands; Peak = most intense passages of play; PC = possession chain; LPS = Local Positioning System; NR = not reported

Match physical activity demands

Distance

Studies observing the match distances covered by players typically compared between high calibre and low calibre players (based on coaches ratings of individual performances), playing positions, and as a result of rotation number and duration. Players in AF cover TD ranging from 11,600 – 13,700 m during a match with a relative distance of 129 ± 8 $m.min^{-1}$ (109 – 145 $m.min^{-1}$) (Table 2.4). The majority of the match (>70%) is performed at speeds under the HSR thresholds (Table 2.4). Three studies examined the differences in physical output between high calibre and low calibre players (Johnston 2012; Johnston et al., 2015; Johnston et al., 2016). These studies reported that high calibre players cover greater TD, but similar relative distances to low calibre players (Johnston 2012; Johnston et al., 2015; Johnston et al., 2016). Differences in playing positions were examined by six studies (Brewer et al., 2010; Coutts et al., 2015; Dillon et al., 2018; Hiscock et al., 2012; Ryan et al., 2017; Wisbey et al., 2010). Nomadic players (midfielders, small forwards and backs) were reported to cover greater absolute and relative distances (Brewer et al., 2010; Coutts et al., 2015; Hiscock et al., 2012; Ryan et al., 2017; Wisbey et al., 2010), and were additionally rotated more frequently than key position players (rucks, tall forwards and backs) (Dillon et al., 2018; Wisbey et al., 2010). Studies examining the influence of interchange rotations on activity demands during a match demonstrated that there is an association between the number of rotations a player has to the relative distances covered (Mooney et al., 2013; Ryan et al., 2017). Additional studies demonstrated that athletes are better able to sustain relative distance outputs during shorter on-field stints (~5 min) compared to longer stints (~11 min) (Dillon et al., 2018; Montgomery and Wisbey, 2016). Lastly, two studies reported relative distances are lowest during the early phase of the season (Aughey, 2011; Ryan et al., 2017), though one study examining match distances during finals reported an 11% increase in relative distances covered (Aughey, 2011).

High speed running

Studies reporting on HSR distances covered during AF match-play typically compare between high calibre and low calibre players, playing positions, and on the relationship with successful match performances. The HSR distances AF players typically cover throughout a match range from 1,300 – 4,350 m, with a HSR relative distance of 33 ± 6 $HSm.min^{-1}$ (14 – 43 $HSm.min^{-1}$) (Table 2.4). Players perform up to 295 HSR efforts within a match with approximately 1.6 – 3.2 efforts per minute (Brewer et al., 2010; Johnston et al., 2012; Johnston et al., 2015; Johnston et al., 2016). There is conflicting research regarding whether high calibre or low calibre players complete more HSR, with one study reporting similar results (Johnston et al., 2015), one reporting low calibre players cover more (Johnston et al., 2012), and another study reporting high calibre players cover more (Johnston et al., 2016). Studies investigating playing positions demonstrate that nomadic players cover greater absolute and relative HSR distances than key position players (Coutts et al., 2015, Hiscock et al., 2012; Gronow et al., 2014; Mooney et al., 2011; Ryan et al., 2017). One study investigating the influence of score margin on HSR outputs reported that during close and losing quarters HSR activity was greater than quarters won by large margins (>19 points) (Sullivan et al., 2014b). However, when accounting for possession phase, time spent at high-speeds (>14 km/h) without possession was significantly greater in quarters won than quarters lost (Gronow et al., 2014). Furthermore, longer on-field stint durations and greater TD covered during a stint have been shown to negatively influence absolute and relative HSR distances (Dillon et al., 2018; Mooney et al., 2013). Lastly, studies examining HSR throughout a season demonstrated HSR outputs remain stable from early to late stages (Aughey, 2011; Ryan et al., 2017), however one study reported HSR increased by ~10% during finals (Aughey, 2011).

Peak demands

Various methods have been used to determine the peak demands on players during AF matches. Using a rolling window approach, peak 3-min relative distances ranged from 160 – 175 m.min^{1} for both less (<5 years) and more (>5 years) experienced players (Black et al., 2016), while one-min peak periods are reported to be 199 – 223 m.min^{-1} (Delaney et al., 2017). Longer periods (10 min) show most playing positions cover similar relative distances (138 – 141 m.min^{-1}), except for tall forwards who have the lowest peak demands (131 m.min^{-1}) (Delaney et al., 2017). The greatest peak HSR relative distances (using a one-min rolling window) are covered by small forwards (110 HSm.min^{-1}), shortly followed by midfielders, small backs, and tall forwards (95 HSm.min^{-1}) (Delaney et al., 2017). During shorter rolling durations (1 – 6 min) as players collected more disposals there was a decline in their peak running relative distances. However, during longer rolling periods (7 – 10 min), when players had up to 0.4 involvements per minute, their peak relative distances increased (Johnston et al., 2019). Peak relative distances also appear to remain stable throughout a season (Corbett et al., 2019).

Table 2.4 Match running demands of Australian Football expressed as mean ± standard deviation and mean (95% confidence intervals).

Author	Total distance (m)	Relative distance ($m.min^{-1}$)	HSR distance (m)	HSR relative distance ($HSm.min^{-1}$)
Aughey (2010)	12,734 ± 1,596	127 ± 17	3,334 ± 756	34 ± 9
Aughey (2011)	NR	128 (119–138)	3,185*	37 (32–35)
Aughey (2013)	NR	140 ± 15	NR	36 ± 14
Brewer et al. (2010)	12,311 ± 1,729	128 ± 12	NR	NR
Corbett et al. (2017)	11,608 ± 3,573	132*	3,198 ± 1,165	36*
Coutts et al. (2010)	12,939 ± 1,145	109*	3,880 ± 633	33*
Coutts et al. (2015)	12,027 (11,158 – 12,819)	115 (108–128)	3,268 (2,598 – 4,314)	32 (25– 43)
Hiscock et al. (2012)	NR	133 ± 12	NR	39 ± 11
Johnston et al. (2012)	13,455 ± 1,764	135 ± 12	3,045m*	30 ± 7
Johnston et al. (2015)	13,556 (13,427–13,685)	130 (116–144)	3,003*	29 (28–29)
Johnston et al. (2016)	13,556 (13,427–13,685)	130 (116–144)	3,003*	29 (28–29)
Kelly et al. (2019)	13,193 (13,047–13,340)	131 (129–132)	3,081*	30 (30–31)
Kempton et al. (2015)	13,447 (12,800–13,400)	124 (121–127)	3,550 (3,300–3,800)	33*
Mooney et al. (2011)	NR	139 ± 11	NR	41 ± 10
Mooney et al .(2013)	NR	135 (129–141)	NR	39 (35–43)
Rennie et al. (2020)	12,135 (11,884–12,384)	133 (131–135)	3,964 (3,830–4,097)	33*
Ritchie et al. (2016)	13,400 ± 1,600	132*	3,246 ± 767	32*
Varley et al. (2014)	12,620 ± 1,872	129 ± 17	1,322 ± 374	14 ± 4
Wisbey et al. (2010)	11,970 + 1,900	117*	NR	NR
Mean	12,782	129	3,160	33
SD	676	8	633	6

Data is expressed as means and standard deviations (±); when standard deviation is not presented in study data is expressed as mean (95% confidence limits); * denotes when measurements were manually calculated; NR = not reported.

Technical demands

Studies examining the technical demands of AF match-play have typically used Champion data to report comparisons between calibre of players, playing positions, efficiency of various skill measures and which technical measures associate to match performance (Table 2.2). These studies showed that players are typically in possession of the ball for less than two seconds at a time and record on average 0.16 disposals per minute (n/min), of which kicks (0.10 n/min) are more prominent than handballs (0.06 n/min) (Johnston et al., 2012; Johnston et al., 2015; Johnston et al., 2016; Ireland et al., 2019; Kelly et al., 2019). Studies reporting the efficiency of skills in AF, inform that handballs are the most efficient skill, hitting the desired target 84% of the time (Parrington et al., 2013) while AF teams average a goal conversion rate of 55% (Anderson et al., 2018). One study demonstrated there is high match-to-match variability for skill involvements, with handballs recording greater variability (44 – 63% coefficient of variation, CV) than kicks (34 – 52% CV) (Kempton et al., 2015). Three studies investigating comparisons between high calibre and low calibre players reported high calibre players have more disposals per minute (0.26 vs 0.12 n/min) and cover significantly less distances per involvement of the ball (42 – 69%) (Johnston et al., 2012; Johnston et al., 2015; Johnston et al., 2016). Similarly, nomadic players have been reported to have more disposals per minute than key position players (0.17 vs 0.11 n/min) (Hiscock et al., 2012), and when accounting for playing experience, more experienced players (>5 years at AFL), regardless of position, have greater skill involvements during and subsequently after peak periods of play (Black et al., 2016). Hit-outs, clearances and inside 50 counts were associated to ladder position in one study (Woods, 2016), while in their raw (absolute) form, inside 50 marks, contested possession, number of goal scorers and higher team median disposals counts associated to desirable match outcomes (Robertson et al., 2016a; Robertson et al., 2016b). Alternatively, in their relative (difference to opposition) form, rebound 50s, meters gained, kicks and inside 50 counts associated to desirable match outcomes (Robertson et al., 2016a; Young et al., 2019b; Young et al., 2019c; Young et al., 2020).

Table 2.5 Description of technical measurements.

Tactical measurement	Description
Clearance	Credited to the player who has the first disposal that clears the stoppage area
Contested possession	Possession obtained during a contest or physically pressured situation
Disposal	Summation of kicks or handballs
Disposal efficiency	Summation of kicks and handballs that hit their target
Effective handball	A handball to a teammate that hits the intended target
Effective kick	A kick of more than 40 metres to a 50/50 contest or better for the team or a kick of less than 40 metres that results in the intended target retaining possession.
Goal conversion	Shot that resulted in a goal
Goal conversion rate	Summation of shots that resulted in a goal
Handball	Disposing of the ball with a closed fist while it rest on the opposing hand
Hit-out	Knocking the ball out of a ruck contest following a stoppage with clear control
Inside 50 m count	Number of times the ball entered the attacking 50 m zone
Kick	Disposing of the ball with any part of the leg below the knee including kicking the ball off the ground
Mark	Attaining possession by catching the ball from a kick that has travelled minimum 15 m before it touches the ground or is impeded by an opposing player
Meters gained	Net distance a team moves the ball towards their goal by either running, kicking or handballing
Player rank	Scientifically derived, objective measure of player performance weighted in favour of effective ball use and winning the disputed ball
Rebound 50	Moving the ball from the defensive 50 m zone into the midfield or attacking 50 m zone
Tackle	Using physical contact to prevent an opposition in possession of the ball from getting an effective disposal
Time in possession	Total duration a team is in possession for the match
Turnover forced score	Scoring as a result of forcing a turnover from the opposition

Tactical demands

Three methods have been used to examine the tactical strategies of various teams in AF, shown in Table 2.2. One study utilised spatiotemporal data to examine how specific match contexts – field position and phase of play – influence team collective behaviours (Alexander et al., 2019). Three studies utilised complex network analysis (CNA) to examine the passing interactions within a team (Braham and Small, 2018; Sheehan et al., 2020b; Taylor et al., 2020), while three studies utilised social network analysis (SNA) to identify the relationships between particular players in a team, providing insight into the functionality and efficiency of a group (Sargent and Bedford 2013; Young et al., 2019a; Young et al., 2020). The key variables of these three analysis methods and their descriptions are shown in Table 2.6. Spatiotemporal data highlighted that field position has more of an influence on the x-axis centroid, while phase of play has more of an influence on the width, length and surface area covered by a team (Alexander et al., 2019). The majority of CNA studies highlighted that successful teams display more measures of clustering coefficients, centrality measures and team entropy (Braham and Small, 2018; Sheehan et al., 2020b). Whereas, studies using SNA reported an association between edge count, transitivity, edge density and match performance (Young et al., 2019a; Young et al., 2020), and that team selection has an impact on the final score margin (Sargent and Bedford 2013). Both network analysis methods identified that greater scoring outcomes are associated with smaller average path lengths and eigenvector centrality measures (Braham and Small, 2018; Young et al., 2019a). One study looking at network measures initiated from kick-ins demonstrated that, network characteristics do not differ between successful and unsuccessful teams, however, teams displaying lower density and higher entropy had more desirable outcomes (leading to a score) following a kick-in (Taylor et al., 2020).

Table 2.6 Description of tactical analysis key variables used in AFL.

Tactical measurement	Description
Collective behavioural variables	
x-axis centroid	Mean longitudinal position of all players
y-axis centroid	Mean transverse position of all players
Length	Distance between the most forward and most backward player
Width	Distance between the two most lateral players
Surface area	Total space covered by a single team
Passing network variables	
Average path length	Average number of passes that occur between all possible pairs of players
Betweenness centrality	The extent to which a team's passing network relies on particular players
Closeness centrality	How well-connected and central a player is within the teams passing structure
Clustering coefficient	The extent to which a player passes with a particular set of players
Degree centrality	The number of players that each player within the team has a direct (i.e. 1 pass) connection to
Entropy	The unpredictability of who a particular player will pass to
Edge count	Total number of interactions between players via effective passes
Edge density	Number of connections between players via effective passes, relative to the total number of possible connections
Eigenvector centrality	Dependence of a team to rely on a small group of players that have a large number of interactions with a large number of other players
Out-degree (in-degree)	Number of different players a particular player has either passed to (or received) a pass from
Out-strength (in-strength)	Number of passes (or received) or shots made by a player
Transitivity	The number of triads in a team, in proportion to the total possible number of triads. A triad represents the concept that two players are connected via a third player

Interaction of match-play elements

Studies that analysed physical and technical constructs of match-play typically examined the association between physical measures and skill involvements (Dillon et al., 2018; Hiscock et al., 2012; Mooney et al., 2011), their relationship to player performance based on both subjective (coach's rating) and objective measures (player rank) (Bauer et al., 2015; Dillon et al., 2018; Johnston et al., 2012; Mooney et al., 2011; Sullivan et al., 2014a) and how score margin influences both constructs (Sullivan et al., 2014b). Likewise, studies investigating technical and tactical constructs have demonstrated how technical skill measures are mediated by tactical strategies (Woods et al., 2017) and the contribution each construct has on match outcome (Young et al., 2020). These studies typically isolate and compare constructs of match-play as oppose to integrating and understanding their relationship to one another. Recent research has looked to integrate data sources by examining physical and technical constructs during individual possession chains (Rennie et al., 2020). This study reported that when accounting for technical skill involvements, attacking and defensive possession chains have similar activity demands (Rennie et al., 2020). Additionally, compared to stoppages, attacking and defensive chains involved the most HSR demands (Rennie et al., 2020).

2.4 Discussion

This systematic review summarises the three key constructs of AF match-play and outlines how recent research has looked to integrate data from multiple constructs during individual possession chains. Proceeding the screening process, 46 studies were identified to have analysed either the physical, technical, or tactical constructs of AFL match-play. While physical and technical constructs have been studied extensively, tactical elements have only recently been investigated with six of the seven studies identified in this review conducted in the last three years. Furthermore, constructs of match-play are typically analysed in isolation, with few studies incorporating more than one construct. To date, no study has investigated the influence that tactical constructs have on the activity demands of AF athletes or has integrated data sources from all three constructs of match-play.

Summary of physical constructs

The present systematic review showed that physical demands of match-play are the most commonly investigated construct of AF performance. Whilst, there are out-of-game contextual factors (i.e. travel and sleep quality) that can affect absolute and relative distances covered in a match (Richmond et al., 2007) they were outside the scope of this review. Rather, playing position and the calibre of player were the main comparisons (N = 9) undertaken by studies within this review. Six studies, which all examined different cohorts of players from various clubs identified nomadic players as covering the greatest absolute and relative distances (Brewer et al., 2010; Coutts et al., 2015; Dillon et al., 2018; Hiscock et al., 2012; Ryan et al. 2017; Wisbey et al., 2010). However, given their tactical roles within the team (be the link between the offence and defence), and the observation that they are the most rotated group (allowing greater recovery from transient fatigue) (Dillon et al., 2018; Wisbey et al., 2010) the findings are unsurprising. Similarly, three studies reported high calibre players cover greater TD, although both high calibre and low calibre players cover similar relative distances (Johnston et al., 2012; Johnston et al., 2015; Johnston et al., 2016). High calibre players are generally older, more experienced and are on the ground for longer periods of time (106 min vs 96 min). As such, high calibre players cover greater absolute distances, but run at similar relative distances due to their greater match awareness and on-field playing times. Furthermore, relative distances covered during a match seem to be linked with match significance with two studies (Aughey, 2011; Ryan et al., 2017) detailing that relative distances are highest at the terminal end of the season and increase a further 11% during the finals campaign (Aughey, 2011). As the finals are made up of the best eight performing teams of the year, relative distances may be increased due to the quality of opposition with one study in AF indicating an association between the pair (Ryan et al., 2017).

Although the majority of time in AF match-play is performed at low-to-moderate speeds (i.e. <14 km/h), AF players require intermittent bursts of high-speed efforts throughout a match. Similar to absolute and relative TD covered, nomadic and high calibre players have been shown to spend more of the match at high speeds than their key position and low calibre counterparts (Coutts et al., 2015, Hiscock et al., 2012; Gronow et al., 2014; Johnston et al., 2016; Mooney et al., 2011; Ryan et al., 2017). However, this is in contrast with other studies that demonstrated low calibre players spend more or at least similar match times at high speeds (Johnston et al., 2012; Johnston et al., 2015). These inconsistencies in results demonstrate that HSR demands may be reflective of tactics employed (Greenham et al., 2017), the demographic of the playing list (i.e. proportion of high-to-low calibre players) (Johnston et al, 2012), opposition strength (Ryan et al., 2017) and the measurement error of different GPS units (Cummins et al., 2013).

Furthermore, irrespective of score margin, when the team is not in possession of the ball HSR demands are greater, suggesting that defensive phases of play are more physically demanding than attacking phases (Gronow et al., 2014). Lastly, although HSR demands remain stable across the season (Aughey, 2011; Ryan et al., 2017), the finals series increase HSR by almost 10% (Aughey, 2011). Evidence from other football codes have found matches against stronger opposition have small-to-moderate increases in HSR distances (Kempton and Coutts, 2016), potentially explaining the findings from those in AF.

Peak periods of play have recently been investigated in AF to add more specificity to training design and prescription (Black et al., 2016; Delaney et al., 2017). In total, four studies investigated the peak running demands in AF (Black et al., 2016; Corbett et al., 2019; Delaney et al., 2017; Johnston et al., 2019). The use of 'peak periods' analysis has been undertaken using various methods. Using fixed three-minute windows, less and more experienced players show similar peak speeds covered during a match (Black et al., 2016). However, experienced players demonstrated greater running outputs following peak passages of play (Black et al., 2016), suggesting that experienced players are more equipped to tolerate the transient fatigue associated with peak periods of play due to their longevity in the AFL system. Similar to global demands of match-play, the tactical role of nomadic payers sees them cover greater peak relative distances and peak HSR distances (Delaney et al., 2017). Only two of the studies combined peak period activity demands with the technical involvements of players (Corbett et al., 2019; Johnston et al., 2019). These studies highlight the importance of this interaction, showing that with greater skill involvements, players typically have lower physical output. However, studies examining peak demands only account for a small portion of match time, meaning that the data is not reflective of whole match, quarter or possession chain (i.e. attack or defence) demands, but rather specific to particular moments in a match. Therefore, combining technical and physical data sources during greater time periods (i.e. quarter or combined possession chains) is an area that requires further investigation. This would assist practitioners in understanding how skill involvements influence activity demands, with the data subsequently being used to enhance athlete preparedness by designing training drills that are representative of the physical and technical demands of match-play.

Summary of technical constructs

Technical output was identified to be influenced by the calibre of player (Johnston et al., 2012; Johnston et al., 2015; Johnston et al., 2016) and the individual's playing position (Hiscock et al., 2012) in this review. Nomadic players were shown to have greater disposals per minute than key position players in one study (Hiscock et al., 2012). This was explained to be related to the tactical role of nomadic plays (i.e. they are clearance and linking players to the offence and defence), which allows these individuals to gain more possession than key position players. Alternatively, high calibre players have been demonstrated to travel less distance per disposal in three studies (Johnston et al., 2012; Johnston et al., 2015; Johnston et al., 2016), suggesting that better performing athletes have greater match awareness and are able to have lower overall physical output while having a positive influence on the match. While research demonstrated that better performing individuals and teams have lower activity demands, no research has recorded the influence that specific technical skill involvements (i.e. kicks or handballs) have on the physical output of players in AF. One study reported the distribution of physical and technical output in various phases of play (Rennie et al., 2020), however, the specific influence of skill-based match events on the physical output of players during competitive matches remains unclear. This type of research is important in understanding what influence various possession types have on the activity demands of AF athletes and not just generalising the findings. Which may limit a practitioner's ability to design training drills, tactical strategies and analyse player performance.

The present review showed that numerous skill measures have been reported to have an association with match performance. Indeed, it has been suggested that coaches should focus on winning clearances and setting up attacking structures that generate more marks inside 50 and repeat entries (Robertson et al., 2016a; Woods et al., 2016; Young et al., 2019b; Young et al., 2019c; Young et al., 2020). Additionally, teams should aim to increase their unpredictability of ball movement by spreading the ball amongst players and having multiple targets for goal rather than one-or-two specific players (Robertson et al., 2016b). Collectively, these studies highlight the need for combining technical and tactical analysis so that coaches can understand the efficiency of their team's ball movement and if the team's technical output is reflective of the way in which the team wants to move the ball. Additionally, with the integration of technical and tactical data coaches can analyse opposition tactics and begin to design defensive structures that will prevent scoring opportunities for the opposition, whilst simultaneously setting up tactics that can exploit the opposition during attacking phases.

Summary of tactical elements

The three identified tactical analysis methods reported in this review allow coaches to analyse and practice tactical strategies aimed at enhancing performance. Using the methodology of the study examining spatiotemporal data (Alexander et al., 2019), coaches can analyse and practice collective team positioning associated with various scenarios during competitive matches. Likewise, using the result of the network analysis studies (Braham and Small, 2018; Sargent and Bedford 2013; Sheehan et al., 2020b; Taylor et al., 2020; Young et al., 2019a; Young et al., 2020) coaches can implement tactical strategies characterised by unpredictable and faster ball movement to try to increase their chances of winning matches. However, while the findings of this review support the use of the identified tactical analysis methods to examine the collective behaviours and passing networks of AF teams, it is understood that in isolation these insights are limited. Therefore, future research examining match performance based on tactical strategies should integrate spatiotemporal or network analysis data with either physical and/or technical data to enhance understandings of the activity demands and skill-based match events associated with various tactical strategies ending in desirable outcomes.

Influence of integrated data sources

The majority of studies identified in this review that have integrated data sources from multiple constructs typically compared between physical and technical measures and their influence on both individual and team performances (Bauer et al., 2015; Dillon et al., 2018; Johnston et al., 2012; Mooney et al., 2011; Sullivan et al., 2014a). While this has provided knowledge on how match performance is more favourably weighted towards technical measures, this form of analysis fails to provide an understanding of the interaction between constructs of match-play. Physical, technical and tactical constructs are inextricably linked, however the relationship between these constructs may be affected by different contextual factors within a match and therefore should be investigated accordingly. Recent research examining individual possession chains have reported associations between different constructs of match-play by integrating data from multiple sources (Rennie et al., 2020). This study reported that attacking and defensive phases of play have similar physical demands despite attacking chains having more skill involvements (Rennie et al., 2020), which had previously been related to lower physical activity (Johnston et al., 2019). This may be explained by common tactics in AF which see attacking teams attempting to spread the defence and utilise fast ball movement once in possession of the ball (Rennie et al., 2020). This tactic aims to spread the defence and create more avenues to goal (Frencken et al., 2011). Nevertheless, the findings from this study highlight the importance and need for more integrated research. With such an approach coaches could design tactical strategies that aim to control the speed of the game based on the physical demands associated with different technical skill measures (i.e. kicks vs handballs or player involvements). Furthermore, coaches could analyse the specific behaviours of individual players during various tactical scenarios (i.e. following a turnover) by integrated data sources from physical and tactical constructs. This, in comparison to previous isolated studies, would provide greater insights into match performance, as well as provide practitioners with a more comprehensive data source for training drill design and prescription.

Limitations

A limitation to this review was the lack of homogeneity in the HSR thresholds amongst studies. Among the 30 studies investigating physical demands, five different thresholds were used for the term HSR ranging from 14 – 20 km/h. Additionally, different models of GPS units were utilised posing further issues with comparative analyse due to the dissimilarity in the hardware and satellite systems used (i.e. sampling frequency, GPS vs GNSS), the greater error in the earlier hardware, and additionally the software (i.e. algorithms to smooth data) used to collect and analyse the data. Furthermore, only two studies in this review used multi-team analysis for physical demands of match-play, limiting the understanding of how match activity demands are influenced by unique tactical strategies of various teams and the demographic of a team. Additionally, although recent research has integrated data sources from two separate constructs, they are still limited by not incorporating all three constructs of match-play.

Another limitation to this review include the inappropriate analysis methods undertaken by most studies. Most studies in this review used analysis methods (i.e. repeated measures) that are more susceptible to bias, do not account for levels of clusters (i.e. hierarchical data), and are unable to handle common analytical issues such as missing data, potentially leading to misinterpretation of the results of these studies. Furthermore, the lack of consistency of methods, positional groups, speed thresholds, and skill variables measured prevent a meta-analysis from being conducted. Consistency across studies would be beneficial to practitioners by having normative values that can be compared between studies. Lastly, most studies in this review fail to account for in-game contextual factors that can influence the activity demands of players during match-play such as field location or the phase of play. This provides practitioners with no context into how activity demands occurred, making it harder to analyse match performance and design training drills representative of match context.

Future directions

Future research should aim to conduct multi-team analysis. Although still uncommon in the AFL, such an approach would serve to provide more generalisability of the results. Additionally, studies should look to analyse all three constructs of match-play in cohesion to develop a holistic understanding of match activity demands. To account for analytical limitations in previous studies, it is essential that appropriate methodologies such as mixed models be used in future physical activity analyses. Future research should continue to expand on possession chain analysis, which provides a more in-depth understanding of the activity demands occurring in match-play compared to whole, half, or quarter match analyses. This research should be expanded by analysing other possession chain factors such as the starting field location or the technical skill measures (i.e. number of kicks or handballs) occurring in various possession chains. This would assist coaches in designing tactical strategies, as well as design training drills that are representative of specific match context. Lastly, to conduct a meta-analysis of activity demands in AF there needs to be more consistency in the definitions and methodologies employed.

2.5 Conclusion

The quantification of how all three elements of match-play are related is important for understanding the locomotive demands of athletes during competitive matches, and for when designing training drills that replicate specific match conditions. This review has identified the global and peak running demands of AF match play, the frequency and efficiency of various technical skills, contextual factors that influence technical demands and the common tactical analysis methods of AF. Match running demands in AF are reliant on numerous technical and tactical variables that are uniquely different dependant on the team investigated. However, this review highlighted that despite an extensive body of literature on match locomotive demands, there is a lack of data surrounding the influence that technical and tactical variables have on the physical output of AF athletes. As such, despite recent attention, more integrated research is required, which will provide deeper understandings into match performance, be a greater tool for match-analysis, and provide practitioners with a greater resource for training design.

Chapter Three

Possession Chain Factors Influence Movement Demands in Elite Australian Football Match-play

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3.1 Abstract

Contemporary analysis of physical activity in Australian Football (AF) are typically presented as a total measure and independent of game context, which is not representative of how the game is played and/or assessed by coaches. This study examines the activity profile of individual possession chains and determines the influence that field position, initial chain state, and possession phase have on these activity characteristics in men's AF. Global positioning system data was attained from 35 players in 13 matches across the 2019 Australian Football League season. Matches were coded into different possession phases, initial field location of the ball, and initial chain state. Mixed models were built to observe the influence of field position and initial chain state for each possession phase. Less TD and HSR distance were covered during attacking chains in the forward 50 and attacking midfield, while defensive chains covered less TD and HSR in the defensive 50 and defensive midfield ($p < 0.001$). Significant main effects for possession phase and initial chain state were observed for TD and HSR. TD and HSR were higher during attacking chains, while chains beginning from a stoppage were lower than intercept and kick-ins ($p < 0.001$). Overall, the most intense moments of the game appear similar across all possession phases when field location is accounted for and that transitioning the ball quickly from the defensive end of the field results in greater physical activity. These findings can be used for prescription and monitoring of training drills specific to AF requirements.

Keywords:

GPS; team sport; time-motion analysis; Tactics

3.2 Introduction

Many of the initial Australian football (AF) match analysis studies reported the absolute and relative match physical activity characteristics (Bauer et al., 2015; Brewer et al., 2010; Coutts et al., 2010). These studies enhanced the understanding of overall activity demands during match-play, which was then used to inform training design. More recently, several studies have used both discrete and rolling time periods to contrast the peak demands experienced during match-play with the traditional global metrics (Delaney et al., 2017; Varley et al., 2012). This understanding of peak physical activity requirements allows practitioners to tailor their physical preparation programs for the most physically demanding periods encountered during match-play. While these studies have provided important information on the physical activity requirements during match play, they are removed from technical and tactical considerations, which are two important constructs of match performance (Impellizzeri and Marcora, 2009). To better incorporate the multiple constructs of performance, several recent studies have examined the effects of both team and player level contextual factors on match activity profiles (Ryan et al., 2017; Sullivan et al., 2014a).

Australian Football match-play is characterised by an ongoing contest for possession between opposing teams. Therefore, one particularly important contextual factor to consider is the effect of possession on match running activities. Indeed, recent research has examined the influence of possession on match activity profiles, showing higher running outputs in defence compared to when a team has possession of the ball (Gronow et al., 2014). While profiling the physical activity demands of different phases is an important development, deeper analysis of the contextual factors associated with possession chains (a chain of play in which the opposition has not won possession of the ball or created a stoppage) (AFL Prospectus, 2018) are warranted. We expect that physical activity will be influenced by the initial event – either a kick-in, intercept, or stoppage – due to differences in player density and tactical objectives at the start of a possession chain. Furthermore, we hypothesise that the starting location of a possession will also influence the movement demands during a chain due to differences in tactical strategies, spatial constraints, and density of players along the length of the ground (Alexander et al., 2019).

Despite the importance of these contextual factors, no studies have examined the influence of either the location or initial starting event of a possession chain on physical activity characteristics. In professional AF clubs, analysis of technical and tactical performance typically involves segmenting the match into individual possession chains and incorporating additional factors such initial chain event and field location. We consider it rational to also examine the movement demands of players within these specific phases. As such, the aim of this study is to examine the influence of starting field position and initial chain state on the physical activity characteristics of elite male AF players during the different phases of possession.

3.3 Methods

Experimental approach

This was a longitudinal observational study of a single team during the 2019 Australian Football League (AFL) season. Thirty-five professional male AF players took part in the study (mean ± SD; age = 25 ± 4 y; mass = 87.1 ± 8.1 kg; height = 188.6 ± 8.0 cm) who were all contracted to the same football club. Only data collected from games on outdoor playing stadiums (n = 13; 4 wins, 9 losses) were included in this study, as matches played indoors used a different measurement system. Players were divided into six positional groups: midfielders (n = 7), mobile defenders (n = 6), mobile forwards (n = 9), tall forwards (n = 5), tall defenders (n = 5), and rucks (n = 3). There were 274 individual match observations included for analysis. Institutional ethics approval (approval number: S17-080) were obtained prior to data collection.

Methodology

The movement profiles of players during competition were assessed using portable GPS units sampling at 10 Hz (Catapult S5, Catapult Innovations, Melbourne, Australia). The validity and reliability of these units has been previously reported (Thornton et al., 2019). The GPS unit was worn in a customised pouch fitted inside the player's jersey, positioned in the middle of the back, slightly superior to the scapulae. All units were turned on ~15 minutes prior to the start of each match. Post-match data was downloaded using Catapult proprietary software (Openfield version 1.22.2, Catapult Innovations, Melbourne, Australia). All bench time was excluded so that only on-field playing time was included for further analysis. A raw time-stamped data file was obtained for each match file and exported for further analysis.

Possession chain data was obtained via manual notation by an experienced analyst (2 years). Four different camera views were provided, with one camera positioned behind the goals at each end, another lateral to the playing field and the fourth was a commercial broadcast feed which was a composite of various camera angles for optimal viewing of match-play. Possession chains were coded for possession phase (attack, defence, dispute, out of play), location at the start of each phase (defensive 50 (D50), defensive midfield (DM), attacking midfield (AM), and forward 50 (F50)), and initial chain state (kick-in, intercept, stoppage). The definitions for the methods of beginning a possession chain are: kick-in; when a player kicks the ball back into play after an opposition behind, intercept; any possession that is won that breaks an opposition possession chain, or stoppage; set piece where the ball is returned to play after a goal, out of bounds, or a ball up being called (AFL Prospectus, 2010). The possession phases were coded using similar methods to previous research, which has shown to be reliable when performed by an experienced analyst (Rennie et al., 2018). To assess intra-rater reliability, the first half of five games were analysed twice, separated by three months to decrease retention of information. The typical error and intra-class correlation coefficient for the number of each possession phase type was 0.03 (0.02 - 0.04, 95% confidence interval) and 0.999 (0.998 – 1.000), respectively.

Statistical analysis

The possession chain data was exported from SportsCode (SportsTec Limited, version 11.2.32, Warriewood, Australia) into an xml format which was then imported into an Excel spreadsheet (Microsoft, Redmond, USA). Possession chain data was combined with the raw GPS data using a custom script in the R statistical computing language (R.3.6.1, R Foundation for Statistical Computing, Vienna, Austria). The two data sources were time aligned at the start of each quarter based on when the umpire bounced the ball. The relative total distance (TD) and high-speed running (HSR, >20 km/h) distances covered by each player during each possession chain was calculated.

Individual linear mixed models were constructed to examine the effect of field position and initial chain state on match physical activity characteristics (TD and HSR) by possession phase (attack, defence, dispute). The individual player was included as a random intercept effect in all models. A series of models were constructed using a ‘step up’ strategy starting with a null model. The fixed effects, starting with possession phase were added, followed by either field position or initial chain state for the respective models. The interaction effect between both fixed effects was added in the final model. Each new model was retained if it improved the model information criteria (likelihood ratio test) compared to the previous model. Bonferonni post hoc analyses were completed to identify differences in running outputs within selected factors of interest. Effect sizes (ES) were obtained using the t statistic from the linear models (Rosnow et al., 2000) and interpreted as < 0.10, trivial; 0.10 – 0.30, small; 0.30 – 0.50, moderate; 0.50 – 0.70, large; 0.70 – 0.90, very large; 0.90 – 1.00, almost perfect (Hopkins et al., 2009). All statistical analyses were conducted using the lme4 and LmerTest packages in R statistical software (R.3.6.1, R Foundation for Statistical Computing, Vienna, Austria). Significance was set at $p \leq 0.05$. Data are reported as mean ±95% confidence intervals (CI).

3.4 Results

The mean, median, and standard deviation (SD) of possession chains duration by possession phase are presented in Table 3.1. Time in dispute was the shortest phase of play, while attacking and defensive phases displayed similar average lengths (Table 3.1).

Table 3.1 Duration (s) of individual possession chains during different phases of play.

Phase	Mean	Median	Standard Deviation
Attack	8.7	4.5	11.0
Defence	9.6	4.8	12.4
Dispute	2.1	1.7	1.6
In play	39.8	35.9	28.9
Out of play	21.7	16.1	17.9

An interaction effect between possession phase and field location were observed for both TD and HSR distances (Table 3.2). The TD and HSR distances covered by possession phase and field location are shown in Figure 3.1. Attacking chains starting in the F50 had lower running output than those starting in AM, DM, and D50 zones ($p \leq 0.001$, TD ES = 0.29 – 0.53; HSR ES = 0.09 – 0.24). Attacking chains starting in the AM were also lower than DM and D50 chains for both TD ($p \leq 0.001$, ES 0.27 – 0.30) and HSR ($p \leq 0.001$, ES = 0.09 – 0.16).

Defensive chains starting in the D50 had lower TD ($p \leq 0.001$, ES = 0.27) and HSR ($p = 0.011$, ES = 0.06), output than DM, AM (p ≤ 0.001, TD ES = 0.49; HSR ES = 0.18), and F50 ($p \leq 0.001$, TD ES = 0.55; HSR ES = 0.19). Defensive chains starting in the DM were also lower than AM and F50 for TD ($p \leq 0.001$, ES = 0.27 – 0.35) and HSR ($p \leq 0.001$, ES = 0.12 – 0.13). Defensive chains starting in AM were lower than F50 for TD ($p \leq 0.001$, ES = 0.09), but not HSR. There were no significant differences in either TD or HSR for starting field location when the ball was in dispute ($p > 0.05$).

For all chains starting in the F50, TD covered was lower during attacking chains than both defensive and dispute chains ($p \leq 0.001$, ES = 0.50 – 0.51). Relative HSR in the F50 was greater during dispute chains ($p \leq 0.001$) than both defensive (ES = 0.08) and attacking (ES = 0.25) chains, while defensive chains were also greater than attacking chains ($p \leq 0.001$, ES = 0.18). In the AM zone, attacking chains were lower than both defensive and dispute chains for TD ($p \leq 0.001$, ES = 0.18 – 0.21) and HSR ($p \leq 0.001$, ES = 0.09 – 0.13). In the DM and D50 zones, defensive chains covered lower TD than when in dispute or attack ($p \leq 0.001$, ES = 0.32 – 0.55). Dispute chains also covered lower TD than attacking chains in DM ($p = 0.001$, ES = 0.07) and D50 ($p = 0.036$, ES = 0.06) zones. Relative HSR distance were lower in defensive chains compared to both dispute and attack ($p \leq 0.001$) in both DM (ES = 0.17 – 0.19) and D50 (ES = 0.20 – 0.23) zones.

Table 3.2 Model output for field location and possession phase on running outputs for total distance and high-speed running (HSR) in Australian Football.

	Total Distance					**HSR Distance**				
Predictors	*Estimates*	*CI*	*p*	*df*	*ES*	*Estimates*	*CI*	*p*	*df*	*ES*
(Intercept)	140.2	135.5 – 144.9	<0.001	52.7		11.9	9.8 – 14.1	<0.001	67.5	
Phase: Defence	17.1	14.0 – 20.1	<0.001	3493.8	0.18	4.7	3.0 – 6.5	<0.001	3491.0	0.09
Phase: Dispute	19.4	16.3 – 22.4	<0.001	3493.8	0.21	6.9	5.2 – 8.7	<0.001	3491.0	0.13
Zone: D50	26.0	23.0 – 29.0	<0.001	3493.8	0.27	5.7	4.0 – 7.5	<0.001	3491.0	0.11
Zone: DM	28.8	25.8 – 31.8	<0.001	3493.8	0.30	8.5	6.8 – 10.3	<0.001	3491.0	0.16
Zone: F50	-28.0	-31.0 – -25.0	<0.001	3493.8	0.29	-4.8	-6.5 – -3.0	<0.001	3491.0	0.09
Defence * D50	-76.9	-81.2 – -72.7	<0.001	3493.8	0.51	-15.5	-18.0 – -13.1	<0.001	3491.0	0.20
Dispute * D50	-24.7	-28.9 – -20.4	<0.001	3493.8	0.19	-5.3	-7.8 – -2.8	<0.001	3491.0	0.07
Defence * DM	-54.6	-58.8 – -50.3	<0.001	3493.8	0.39	-14.9	-17.4 – -12.5	<0.001	3491.0	0.20
Dispute * DM	-26.2	-30.4 – -21.9	<0.001	3493.8	0.20	-8.1	-10.6 – -5.6	<0.001	3491.0	0.11
Defence * F50	36.3	32.1 – 40.6	<0.001	3493.8	0.27	5.1	2.6 – 7.6	<0.001	3491.0	0.07
Dispute * F50	32.7	28.4 – 37.0	<0.001	3493.8	0.25	6.9	4.5 – 9.4	<0.001	3491.0	0.09
Random Effects										
σ^2	349.3					118.1				
τ_{00}	156.1					25.7				
ICC	0.31					0.18				
N	35					35				
Observations	3539					3539				

D50, defensive 50; DM, defensive mid; F50, forward 50; CI, 90% confidence interval; df, degrees of freedom; ES, effect size.

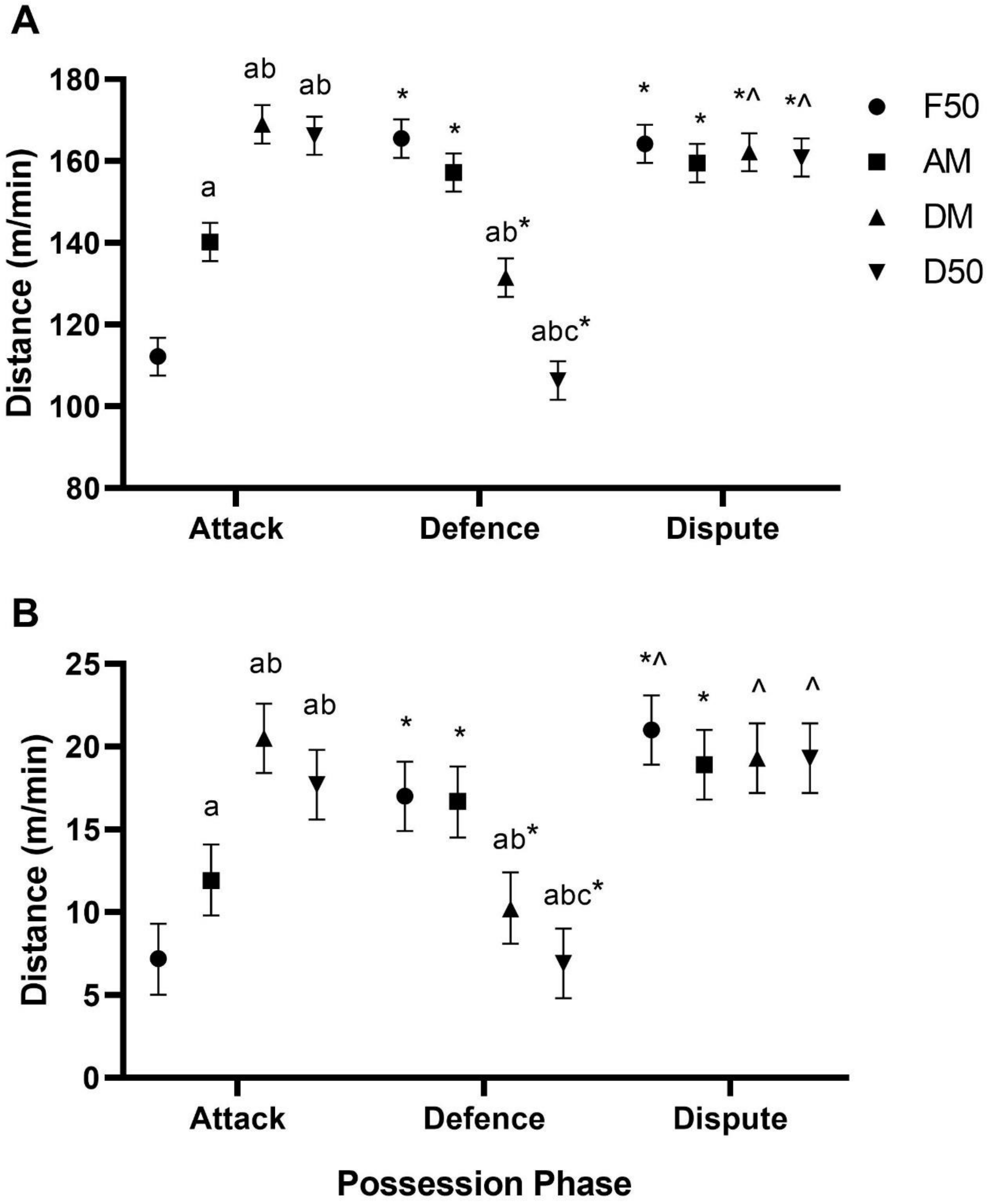

Figure 3.1 Relative total distance (A) and high-speed running distance (B) covered during Australian football match-play by possession phase and field location (F50, forward 50; AM, attacking midfield; DM, defensive midfield, D50, defensive 50). Data are presented as mean ± 95% CI. Significant differences (p <0.05) are shown for field position ([a] different to F50; [b] different to AM; [c] different to DM) and possession phase ([*] different to attack; [^] different to defence).

There was no interaction, but significant main effects were observed between possession phase and initial chain state for relative TD and HSR distance (Table 3.3). The TD and HSR distances by possession phase and initial chain state are shown in Figure 3.2. Both relative TD (ES = 0.18) and HSR (ES = 0.09) were greater during attacking compared to defensive chains ($p \leq 0.001$). Chains beginning from a stoppage had lower TD than those starting from an intercept ($p \leq 0.001$, ES = 0.41), which were both lower than from a kick-in ($p \leq 0.001$, ES = 0.63, 0.33). Relative HSR distance from stoppages was lower compared to kick-ins ($p \leq 0.001$, ES = 0.16), which were both lower than intercept chains ($p \leq 0.001$, ES = 0.27, 0.12).

Table 3.3 Model output for initial chain state and possession phase on running outputs (m) for total distance and high-speed running (HSR) in Australian football.

	Total Distance					**HSR Distance**				
Predictors	*Estimates*	*CI*	*p*	*df*	*ES*	*Estimates*	*CI*	*p*	*df*	*ES*
(Intercept)	158.3	154.2 – 162.3	<0.001	48.0		17.6	16.0 – 19.1	<0.001	71.3	
Phase: Defence	-7.2	-9.1 – -5.3	<0.001	1731.5	0.18	-2.0	-3.0 – -0.1	<0.001	1732.6	0.09
Chain Start: Kick-In	17.2	14.9 – 19.5	<0.001	1731.5	0.33	-3.2	-4.4 – -1.9	<0.001	1732.6	0.12
Chain Start: Stoppage	-22.5	-24.8 – -20.1	<0.001	1731.5	0.41	-7.5	-8.8 – -6.2	<0.001	1732.6	0.27
Random Effects										
σ^2	416.6					122.1				
τ_{00}	110.1					11.2				
ICC	0.21					0.08				
N	35					35				
Observations	1769					1769				

CI, 90% confidence interval; df, degrees of freedom; ES, effect size.

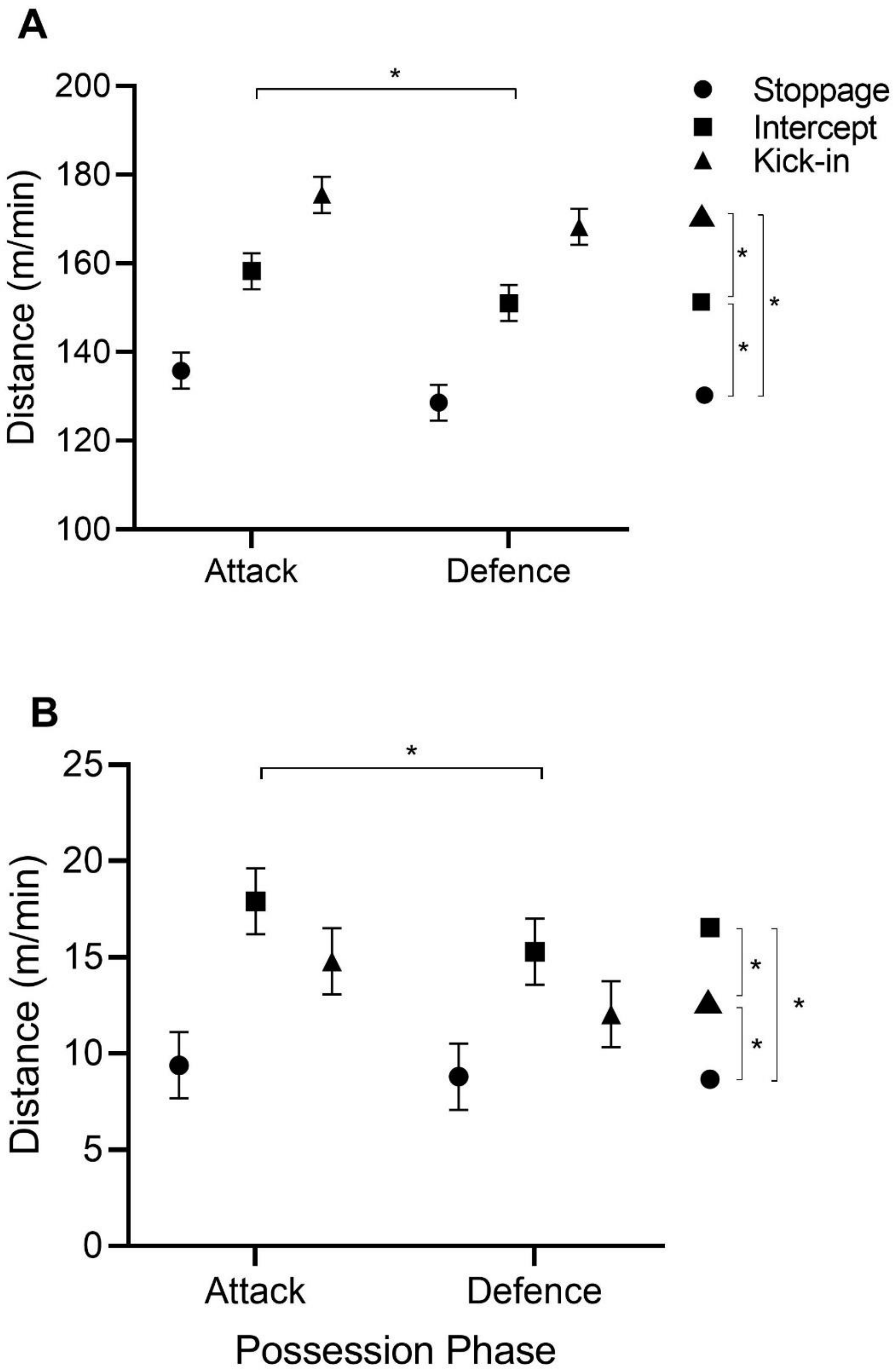

Figure 3.2 Relative total distance (A) and high-speed running distance (B) covered during Australian football match-play by possession phase and initial chain state. Data are presented as mean ± 95% CI. Significant main effects (p <0.05) are shown by solid lines.

3.5 Discussion

This is the first study to describe the influence of field location and initial possession chain state on player movements in professional men's AF. Periods of dispute had the greatest physical activity characteristics regardless of starting field location, along with attacking or defending the full length of the field. Possession chains that originate from a kick-in or intercept resulted in greater physical activity in comparison to those originating from a stoppage. The present findings may assist coaches with preparing their athletes for the specific physical activities they can be exposed to during match-play. In addition, this provides new information on the influence of in-game contextual factors and match tactics on the physical activity characteristics during different possession phases.

Our results showed that the running intensities (TD and HSR) were greater when attacking from the back half of the field (i.e. D50, DM), than when they attacked from the front half (i.e. AM, F50). Conversely, defending from the front half of the field resulted in greater TD and HSR when compared to defending in the back half (i.e. DM, D50). It is important to note that only trivial to small effects were observed for field position on relative HSR distance, potentially due to increased variability of this metric. Nonetheless, these findings suggest that the distance between the starting ball position and the goals plays a meaningful role in the physical activity requirements of athletes within match-play possession phases. While previous research shows defensive phases of possession elicit greater movement demands than attacking phases (Gronow et al., 2014), this study shows that when starting field position is accounted for, similar physical activity is required in both attacking and defensive phases. The greater distance to travel to goals, as well as the increased width in the midfield due to the oval shape of the ground are likely explanations for these results. Indeed, previous research has shown that greater availability of field space increases physical activity requirements in small sided games (Dellal et al., 2011; Fleay et al., 2018), and that the width of the playing surface is often utilised by attacking teams to spread the defence and create more avenues to goal (Alexander et al., 2019). While the present study only examined the location where a possession chain started, future research should incorporate where a chain both starts and finishes to quantify the subsequent effect of distance that the ball travelled during a possession on player physical activity requirements.

The greatest physical activity for both attacking and defensive phases generally occurred in possession chains beginning with an intercept or kick-in. When a team intercepts the ball, it is more likely that the opposition will not have their defensive zone structures in place, which allows a greater opportunity for the team to score (Frencken et al., 2011). When defensive structures are displaced following an intercept, fast attacking ball movement is more advantageous to capitalise before the opposition can reorganise their defensive structure. Similarly, kick-ins - which can also commence quickly before the opposition has had opportunity to transition into defence - generate greater physical activity in comparison to chains commencing with a stoppage. Indeed, stoppages occur following a break in play and provide teams with an opportunity to set up their tactical structures. Furthermore, stoppages create high player density around the starting location, so the combination of advanced tactical strategies and player congestion are the main reasons for the lower running demands observed during possession chains starting from this event. Taken together, these results show that the tactical and spatial constraints associated with initial chain states affect the activity required during subsequent possession chain.

Australian football match-play is characterised by frequent transitions between different phases of play. We observed that the average attack (8.7 s) and defence (9.6 s) lasted less than ten seconds, often interspersed with even shorter periods of disputed possession (2.1 s). We found that some of the highest physical activity requirements of players occurred in the periods when the ball is in dispute. These result from physically demanding actions – such as chasing a loose ball, chasing an opponent to prevent scoring opportunities, or anticipating a possession gain and positioning themselves accordingly – that are common when the ball is in dispute. Interestingly, unlike attacking and defensive phases, there was no effect for field location on the movement demands when the ball was in dispute. Despite the short nature of possession phases, there was a high variance in duration within each phase type. These short and unpredictable possession chains are in contrast to other sports such as rugby and basketball which are typically characterised by discrete attacking and defensive phases (Gabbett, 2012; Montgomery et al., 2010; Ross et al., 2015). The nature of possession in AF is closer to other 'offside' sports such as soccer which fundamentally revolve around an ongoing contest for possession (Bradley et al., 2013; Rampinini et al., 2009). We observed that the average time 'in play' was approximately 40 s, which was interspersed with an 'out of play' period of ~20 s. This suggests an overall work to rest ratio of 2:1 during AFL match-play, although again these durations were highly variable. Nonetheless, these work to rest ratios provide important information on the physical requirements of match-play and can be used to inform the development of conditioning training programs.

The present study provides a detailed analysis of AF ‘active’ requirements of match-play by excluding all ‘out-of-play’ match time - that is umpire stoppage, goal reset, and time on the bench. The high relative TD (150-160 $m \cdot min^{-1}$) reported in this study during various possession phases are greater than the average total match demands that have been reported elsewhere (~130 $m \cdot min^{-1}$) (Brewer et al., 2010; Coutts et al., 2010; Johnston et al., 2012). Likewise, the average relative HSR intensity (~20 $m \cdot min^{-1}$) is greater than previously reported for average match demands (~15 $m \cdot min^{-1}$) (Brewer et al., 2010). While research examining whole match activity profiles provide a good indication of the global load experienced during AFL matches, our results report on the intensities experienced in specific phases of play, which are higher than the match average. Previous research has attempted to identify the most demanding periods of play using a rolling 5 min peak intensity method (Delaney et al., 2017). However, the advantage of our approach is that analysing individual possession chains are more representative of actual phases of match-play rather than arbitrary time periods. Further, this approach aligns with how coaches and performance staff typically analyse matches. Consequently, training prescription based on the present study will better reflect the demands of certain phases of match-play and therefore serve to improve athlete physical preparation through exposure to these greater intensities.

While this study was the first to examine the influence of possession chain factors on the activity profile of AFL match-play, some limitations should be considered when interpreting the results. Firstly, our data were collected from one cohort of professional AF players during one season and as such reflect the observed team and their tactical strategies adopted during the season. Future research should aim to measure both teams participating in the same match - although multi-centre studies are still uncommon in professional sport. Furthermore, while this study used a random intercept to account for individual player effects, our analyses did not account for playing positional groups. Previous research has shown differences in the movement demands depending on playing position and so future research could examine whether relationships observed between possession phase, field location, and initial chain state found in this study are influenced by playing position. Lastly, the present study examined two external load measures (TD and HSR) which were chosen given they are valid and reliable measures that have been commonly used in previous match analysis research (Thornton et al., 2019). However, the inclusion of other metrics such as accelerations, collisions, or metabolic power, which are key movements in AF, may provide further insights into the activity requirements athletes are experiencing during possession chains. Extension of this research to identify successful versus unsuccessful possession chains, as well as duration and intensity of subsequent possession chains, end field position, and match score and game outcomes will also be beneficial to further our understanding of the in-game contextual influences on player match demands.

3.6 Practical Implications

- Segmenting time-motion data into individual possession chains provides detailed information on the locomotor demands of different match phases. This data provides deeper understanding of the physical requirements associated with various tactical strategies.
- Incorporating information such as the field position and initial chain state provides better context when analysing match activity profile compared with gross measures such as overall relative total distance.
- These results can be used to guide football training drill prescription by providing an understanding of the activity profile from a certain phase of play. For example, when practicing an attacking chain commencing from an intercept or kick-in, coaches can reference the typical locomotor activities provided in this study to ensure that realistic match demands are being replicated.
- Using the framework, the output of individual players can be analysed in different phases of the game. For example, players that run the hardest following a turnover can be identified, allowing a better understanding of the role specific behaviour of players.

3.7 Conclusion

Our study showed that field position and initial chain state influence the activity profile of professional AF athletes across all possession phases during match-play. Attacking from the back half of the field, defending from the front half of the field, and when the ball is in dispute elicit the greatest activity profiles. Additionally, beginning a possession chain from an intercept or kick-in elicit greater player activity than from a stoppage. Contextual information about the location and initial chain state of the possession phase provides a more detailed understanding of player match activity. The present findings demonstrate the physical requirements of different phases of the game and are therefore of interest for coaches when developing tactical strategies. Additionally, they can be used to enhance training prescription and ensure that athletes are physically equipped to implement the team's game style.

3.8 Acknowledgements

The authors have no conflicts of interest to declare.

Chapter Four

Player Involvement within Possession Chains Influence Movement Demands in Elite Australian Football Match-play

4.1 Abstract

Match activity analyses in Australian Football (AF) have provided information on the absolute and peak demands of match-play, in addition to in-game contextual factors influencing activity demands. However, these analyses are often independent of technical and tactical considerations, two important constructs impacting activity demands. This study examined the association of in-game contextual factors and technical skill involvements with the activity demands of elite AF players. Global positioning system data was recorded from 35 players in 13 matches throughout the 2019 Australian Football League season. Technical involvements – player disposal, and defensive pressure applied – were attained from Champion Data, while possession phases and the commencing possession chain event were manually coded. Mixed models were built to examine the influence that possession phase factors and events had on the physical activity profiles of elite AF players. During attacking phases, activity demands were increased when a player had a disposal, a greater number of opposition players applied pressure, and when play was initiated from a turnover ($p \leq 0.001$). During defensive phases, activity demands were greatest when an individual player applied pressure, however also increased when the total number of players applying pressure increased and when play was initiated from a turnover or kick-in ($p \leq 0.001$). Overall, the most physically demanding moments in a chain occurred when a player was directly involved in the play, applying pressure or utilising fast ball movement tactics. These findings can inform training design so activity demands are representative of both attacking and defensive match requirements.

Keywords:

GPS; team sport; time-motion analysis; pressure; skill involvements

4.2 Introduction

The activity demands of Australian Football (AF) match-play have been studied extensively over the last two decades. The widespread use of Global Positioning Systems (GPS), accelerometers, gyroscopes and other technology in professional AF have provided practitioners with numerous external load metrics to both measure and analyse during training and matches. Much of the initial research examined external loads across an entire match or quarters of play to provide an overview of the activity demands of AF match-play (Bauer et al., 2015; Brewer et al., 2010; Coutts et al., 2015). To add further specificity to training drill design and prescription, recent research has examined short, discrete periods of play to identify the peak demands of AF competition which have been linked to the most critical moments in match-play (Black et al., 2016; Delaney et al., 2017; Johnston et al., 2019). Additionally, studies have examined contextual factors that can influence the activity demands of AF players. These studies have demonstrated that when teams spend a greater portion of match-play without ball possession (Gronow et al., 2014), have matches against stronger opposition (Ryan et al., 2017), and when quarters are lost (Sullivan et al., 2014b) activity demands are increased. While these studies have enhanced understandings of the activity demands characteristics of AF match-play, they are often isolated from technical and tactical consideration, two important constructs influencing the activity demands of AF players.

A more granular approach to analysing match activity demands can be achieved by examining movement demands during individual possession chains (passages of play that are controlled by a singular team) (Rennie et al., 2020; Vella et al., 2020). This research has demonstrated that attacking and defensive phases of play have similar activity demands (Rennie et al., 2020; Vella et al., 2020), and that players have more skill involvements during attacking and contested phases of play (Rennie et al., 2020). Furthermore, when accounting for the starting field location and the event that initiated a possession chain (i.e. kick-in, intercept or stoppage) activity demands of AF players are impacted (Vella et al., 2020). These studies, in comparison to previous whole match analyses, are more reflective of the ongoing contest for possession in AF and provide coaches with an understanding of in-game contextual factors that influence activity demands during match-play. Also, by integrating data sources from multiple constructs of match-play, coaches and practitioners are provided with more comprehensive information that can assist in designing training drills more representative of realistic match conditions.

Contextual factors such as field position, initial chain state, and the phase of play are important when examining the activity demands of match-play. However, the influence of technical skill involvements occurring within a possession chain on activity demands outputs remains unclear. Certainly, throughout match-play player movement patterns vary based on tactical scenarios depending on the possession phase. Players can be used as link or clearance players as well as scoring options during attacking phases, subsequently influencing their activity demands. Similarly, a player's physical activity can alter when directly applying pressure to the opposition, reflecting a player's defensive intent. Therefore, this study aimed to examine the influence of the initial chain state, field territory gained, as well as player and opposition technical involvements on the activity demands of professional AF athletes. It was hypothesised that during attacking chains, activity demands would increase for individual players directly involved in the chain, however, would reduce when more players become involved in the play. Additionally, during defensive chains it was hypothesised that individual players applying direct pressure on the opposition would have increased activity demands.

4.3 Methods

Experimental approach

Thirty-five AF players (mean ± SD; age = 25 ± 4 y; mass = 87.1 ± 8.1 kg; height = 188.6 ± 8.0 cm) from the same team during the 2019 AFL season participated in this longitudinal observational study. Data included for analysis was collected from games played at outdoor stadiums only (n = 13; 4 wins, 9 losses), as a different measurement system (local positioning system) is required for matches played indoors. Players were classified as midfielders (n = 7), mobile defenders (n = 6), mobile forwards (n = 9), tall forwards (n = 5), tall defenders (n = 5), and rucks (n = 3). There were 274 individual match observations included for analysis. Institutional ethics approval (approval number: S17-080) was obtained prior to data collection.

Methodology

The activity profiles of players during competition were gathered using previously validated 10 Hz GPS units (Catapult S5, Catapult Innovations, Melbourne, Australia) (Thornton et al., 2019). The GPS units were positioned in the middle and slightly superior to the scapulae of each player in a customised pouch fitted inside the players jersey. Catapult proprietary software (Openfield version 1.22.2, Catapult Innovations, Melbourne, Australia) was utilised to download post-match data. All bench time and out-of-play data was excluded to ensure only active playing time was included for analysis. A raw time-stamped data file was obtained for each match observation and exported for further analysis.

Player involvement and the pressure applied to the opposition were retrieved from match transaction data from a commercial statistical provider (Champion Data Pty Ltd, Melbourne, VIC). These match events were collected for both the observation team and the opposition. A player was reported to be involved if during attacking chains they recorded a kick or handball. A player was deemed to have applied pressure if they performed one of the following defensive actions: made contact with the ball carrier (physical), closed the distance between themselves and the ball carrier (closing), or guarded space to limit the ball carriers direction to run/pass (corralling). Field territory gained (chain distance), defined as the total metres the ball moved forward up the field, was obtained by the field positions XY coordinates from the commencing event to the terminating event in the chain.

Possession chain data was collected via manual notation by an experienced analyst (2 years) using SportsCode (SportsTec Limited, version 11.2.32, Warriewood, Australia), from four different camera angles. One camera was positioned behind each of the goals, one lateral to the playing field and the fourth was a commercial broadcast feed, compromised of various camera angles for optimal viewing of match-play. Possession chains were coded for phase of play (attack, defence, dispute, out of play), ball location at the beginning of each phase (defensive 50 (D50), defensive midfield (DM), attacking midfield (AM), and forward 50 (F50)), and how the phase was initiated (via a kick-in, intercept, or stoppage). Possession phases were coded based on previous research methodologies, which demonstrated high reliability (ICC, r = 0.902–0.992) (Rennie et al., 2018). Definitions for how a phase initiated are as follows: kick-in; when a player kicks the ball back into play after an opposition behind, intercept; any possession that is won that breaks an opposition possession chain, or stoppage; set piece where the ball is returned to play after a goal, out of bounds, or a ball up being called (AFL Prospectus, 2010). Only possession chains that initiated from the defensive half of the field (D50 or DM) or attacking half of the field (F50 or AM), depending if the team was in an attacking or defensive phase, were included for analysis in this study. This allowed for examination of chains that were more likely to transition across a larger portion of the field.

Statistical analysis

The possession chain data and technical skill data were exported from SportsCode and Champion Data, respectively, which were then imported into an Excel spreadsheet (Microsoft, Redmond, USA). Both data sets were combined with the raw GPS data using a custom script in the R statistical computing language (R.3.6.1, R Foundation for Statistical Computing, Vienna, Austria). All data sets were time aligned from when the umpire bounced the ball to signal the start of each quarter. Within every possession chain, all player's relative total distance (TD) and high-speed running (HSR >20 km/h) distances covered were calculated.

Multilevel linear mixed modelling were used to examine the influence of initial chain state, player involvements, and defensive pressure acts on the player activity demands (relative distance and HSR relative distance) during attacking and defensive phases of play (Table 4.1). Separate models were built for attacking and defensive phases of play. This form of analysis contains both fixed effects (describe an association between a dependant variable and covariates for a population) and random effects (representing random deviations from relationships described by fixed effects) (West et al., 2014). The individual player was included as a random effect in both models. Starting with the null model, a 'step up' model construction strategy was employed in this study design. Models were retained if they improved the model information criteria (likelihood ratio test) and demonstrated statistical significance ($p \leq 0.05$) compared to the previous model. Effect sizes (ES) were obtained using the t statistic from the linear models (Rosnow et al., 2000) and interpreted as < 0.10, trivial; 0.10 – 0.29, small; 0.30 – 0.49, moderate; 0.50 – 0.69, large; 0.70 – 0.89, very large; 0.90 – 1.00, almost perfect (Hopkins et al., 2009). All statistical analyses were conducted using the lme4 and LmerTest packages in R statistical software (R.3.6.1, R Foundation for Statistical Computing, Vienna, Austria). Data were reported as mean ±95% confidence intervals (CI).

Table 4.1 Covariates included in model specification for attacking (model 1) and defensive (model 2) phases of play.

Level of data		Factors	Type	Classification
Level 2	Random factor	Player		
Level 1	Unit of analysis	Possession Phase		
	Dependant variable	Relative total distance	Continuous	$m \cdot min^{-1}$
		Relative high-speed distance	Continuous	$m \cdot min^{-1}$
	Covariates	Initial chain state (model 1 +2)	Categorical	Turnover, kick-in, stoppage
		Field territory gained (model 1 + 2)	Continuous	Metres
		Player involved in possession chain (model 1)	Binary	1 = yes; 0 = no
		Total players involved in chain (model 1)	Continuous	Number of players
		Total opposition players applying pressure in chain (model 1)	Continuous	Number of players
		Player directly applying pressure (model 2)	Binary	1 = yes; 0 = no
		Total players applying pressure in chain (model 2)	Continuous	Number of players
		Total opposition players involved in chain (model 2)	Continuous	Number of players

4.4 Results

Lower TD ($p \leq 0.001$, ES = 0.08) and HSR ($p \leq 0.001$, ES = 0.07) outputs were found during attacking chains initiating from a stoppage compared to chains initiating from an intercept, while kick-ins had similar TD ($p = 0.724$), but lower HSR compared to intercepts ($p \leq 0.001$, ES = 0.06, Table 4.2). For every metre increase in the field territory gained, running outputs increased by 0.4 $m \cdot min^{-1}$ for TD ($p \leq 0.001$, ES = 0.15), and 0.25 $m \cdot min^{-1}$ for HSR ($p \leq 0.001$, ES = 0.13). When an individual player was directly involved during attacking chains, their TD ($p \leq 0.001$, ES = 0.06) and HSR ($p \leq 0.001$, ES = 0.10) increased by 10.2 $m \cdot min^{-1}$ and 12.9 $m \cdot min^{-1}$, respectively. For each additional attacking player directly involved during the chain, there is less overall TD (-3.4 $m \cdot min^{-1}$) and HSR (-3.3 $m \cdot min^{-1}$) completed ($p \leq 0.001$). Lastly, for each additional opposition player applying pressure, TD and HSR outputs increased by 2 $m \cdot min^{-1}$ ($p \leq 0.001$).

Lower TD ($p \leq 0.001$, ES = 0.11) and HSR ($p \leq 0.001$, ES = 0.06) outputs were found during defensive chains initiating from a stoppage than those initiated from an intercept, while defensive chains initiating from a kick-in increased TD ($p \leq 0.001$, ES = 0.03), but lowered HSR ($p \leq 0.001$, ES = 0.04) outputs (Table 4.3). For every metre increase in field territory gained by the opposition, TD and HSR outputs increased by 0.32 $m \cdot min^{-1}$ and 0.25 $m \cdot min^{-1}$, respectively. Individual players applying direct pressure to the opposition during defensive chains, increased their TD by 14.4 $m \cdot min^{-1}$ ($p \leq 0.001$, ES = 0.07), and their HSR by 16.9 $m \cdot min^{-1}$ ($p \leq 0.001$, ES = 0.11). Similarly, for each additional defender that applies pressure during defensive chains, running outputs increased by 2.8 $m \cdot min^{-1}$ (TD) and 1.5 $m \cdot min^{-1}$ (HSR). Lastly, as more opposition players became involved in the chain TD (-4 $m \cdot min^{-1}$) and HSR (-3.3 $m \cdot min^{-1}$) outputs were reduced ($p \leq 0.001$).

Table 4.2 Model output of attacking possessions for total distance ($m \cdot min^{-1}$) and high-speed running (HSR, $m \cdot min^{-1}$) in Australian football.

	Total Distance					**HSR Distance**				
Predictors	*Estimates*	*CI*	*p*	*df*	*ES*	*Estimates*	*CI*	*p*	*df*	*ES*
Intercept ($m \cdot min^{-1}$)	148.8	(142.0 – 155.6)	<0.001	39.18		8.2	(5.2 – 11.3)	<0.001	47.12	
Chain Start: Kick-In ($m \cdot min^{-1}$)	-0.5	(-3.0 – 2.1)	0.724	18180	0.00	-7.5	(-9.3 – -5.6)	<0.001	18180	0.06
Chain Start: Stoppage ($m \cdot min^{-1}$)	-17.7	(-20.7 – -14.6)	<0.001	18180	0.08	-10.7	(-12.9 – -8.5)	<0.001	18180	0.07
Field territory gained (m)	0.41	(0.37 – 0.45)	<0.001	18180	0.15	0.25	(0.22 – 0.28)	<0.001	18180	0.13
Player involved (y/n)	10.2	(7.7 – 12.7)	<0.001	18190	0.06	12.9	(11.0 – 14.7)	<0.001	18210	0.10
Attacking players involved (n)	-3.4	(-4.3 – -2.6)	<0.001	18180	0.06	-3.3	(-3.9 – -2.7)	<0.001	18180	0.08
Opposition players involved (n)	2.0	(1.2 – 2.7)	<0.001	18180	0.04	2.0	(1.4 – 2.5)	<0.001	18180	0.05
Random Effects										
σ^2	3498.7					1884.8				
τ_{00}	389.6					66.2				
ICC	0.10					0.03				
N	35					35				
Observations	18214					18214				

CI, 90% confidence interval; df, degrees of freedom; ES, effect size; $m \cdot min^{-1}$, relative distance; m, metres; y/n, yes or no; n = total number of players

Table 4.3 Model output of defensive chains for total distance ($m \cdot min^{-1}$) and high-speed running (HSR, $m \cdot min^{-1}$) in Australian football.

	Total Distance					**HSR Distance**				
Predictors	*Estimates*	*CI*	*p*	*df*	*ES*	*Estimates*	*CI*	*p*	*df*	*ES*
Intercept ($m \cdot min^{-1}$)	153.7	(148.1 – 159.3)	<0.001	39.33		9.7	(6.7 – 12.8)	<0.001	40.88	
Chain Start: Kick-In ($m \cdot min^{-1}$)	5.1	(2.4 – 7.8)	<0.001	19760	0.03	-5.8	(-7.7 – -3.9)	<0.001	19760	0.04
Chain Start: Stoppage ($m \cdot min^{-1}$)	-23.7	(-26.8 – -20.7)	<0.001	19760	0.11	-9.0	(-11.2 – -6.9)	<0.001	19760	0.06
Field territory gained (m)	0.32	(0.29 – 0.36)	<0.001	19770	0.13	0.25	(0.23 – 0.28)	<0.001	19770	0.15
Player involved (y/n)	14.4	(11.5 – 17.3)	<0.001	19770	0.07	16.9	(14.8 – 19.0)	<0.001	19780	0.11
Defensive players involved (n)	2.8	(2.1 – 3.6)	<0.001	19770	0.05	1.5	(1.0 – 2.0)	<0.001	19770	0.04
Opposition players involved (n)	-4.0	(-4.7 – -3.2)	<0.001	19770	0.07	-3.3	(-3.8 – -2.7)	<0.001	19770	0.08
Random Effects										
σ^2	3525.3					1779.5				
τ_{00}	253.5					66.7				
ICC	0.07					0.04				
N	35					35				
Observations	19803					19803				

CI, 90% confidence interval; df, degrees of freedom; ES, effect size; $m \cdot min^{-1}$, relative distance; m, metres; y/n, yes or no; n = total number of players

4.5 Discussion

This study extended previous research investigating individual possession chains by examining the influence of technical skill involvements such as field territory gained, player involvement and defensive pressure applied on the physical activity characteristics in professional AF. Overall activity demands (TD and HSR) increased when greater field territory was gained, irrespective of possession phase. Furthermore, during defensive chains TD and HSR outputs increased when individual players applied pressure or the total number of players applying pressure to the opposition increased. During attacking chains when a player was directly involved in the play their TD and HSR outputs increased, however when more players became involved in a chain TD and HSR outputs reduced. Lastly, for every opposition player that touched the ball during defensive chains, TD and HSR outputs were reduced.

This study is the first to examine the association between technical skill involvements and the physical output of players during individual possession chains. While previous research in AF has reported on the physical and technical output of players during various phases of play (Rennie et al., 2020), we found that during attacking phases, when a player was directly involved in the chain there was an increase in their TD and HSR outputs. Interestingly, despite individual players showing increased activity demands when involved in an attacking chain, this study showed that as more players became involved in the play, collective activity demands were reduced. When more players touch the ball in a chain, it is likely that the ball has taken a less direct path towards goals, potentially due to opposition defensive zones limiting available passing lanes and marks causing short delays in play before the next disposal. Having more players involved in a chain and taking a less direct route to goals during attacking chains can be a useful tactic in retaining possession and controlling the speed of the game, particularly when defensive structures are well set up ahead of play (Taylor et al., 2020). Additionally, it is worth noting that as kicks travel further than handballs, more or less players may be involved in the play due to the type of disposal that the chain is made up of. Nevertheless, teams aiming to implement more direct tactics during attacking chains need to consider the greater physical demands associated with this style of play, compared to tactics involving a greater number of players. To enhance the finding of the present study, future studies should look to quantify the activity demands associated with skill measures that characterise attacking and defensive chains. For example, researchers could examine the players physical outputs during chains predominantly compromised of handballs as opposed to kicks which cover greater distances and allow breaks in play following a mark. Additionally, it may also be useful to examine the quality and execution of skill involvements and their influence on the activity demands of AF players.

The present results showed that during defensive chains TD and HSR outputs of the observation team were negatively associated with the number of opposition players involved in the chain. These results indicate that the physical requirements of teams in defence are related to the tactical strategies of the attacking team. This may be reflective of the rules of AF whereby the attacking team can take a mark and impede opposition pressure for ~six seconds while deciding how to move the ball (Taylor et al., 2020). This is a unique part of AF that differs to other football codes such as soccer, despite both sports being similarly characterised by ongoing contests for possession. However, within this time the opposition also has the opportunity to further organise their defensive structures ahead of play. This may create congestion in the opposition's forward half, leading to more stoppages and less overall distance the opposition has to defend, which has been demonstrated to lower the activity demands of AF players in previous research (Ryan et al., 2017; Vella et al., 2020). While present findings provide information on how the activity demands of teams in defence are associated with the attacking team's tactical strategies, future research should examine specific passing network measures that influence the physical output of defensive players. For example, researchers could examine the association between the frequency of passes and the pace of ball movement on the activity demands during defensive chains. The information could subsequently be used by coaches when designing defensive structures that aim to control the pace of the game by limiting the passing options and desirable movement patterns of the attacking team.

The present study showed that increases in TD and HSR are associated with direct pressure acts. Throughout defensive chains, teams apply pressure on the opposition to regain possession by tackling, bumping, or by lowering the technical proficiency of the ball carrier through perceived pressure (closing an opponent, causing them to rush their disposal). It has previously been suggested that greater HSR demands in defence are due to the pressure that defensive teams put on the opposition (Gronow et al., 2014), however prior to the present study this had yet to be quantified. Nevertheless, coaches aiming to implement high pressure defensive tactics should be aware of the increased physical demands associated with this style of play.

Furthermore, when a greater number of opposition players apply defensive pressure, we observed that the attacking team had increased TD and HSR outputs. Opposition players are unable to apply pressure on the attacking team following a mark, free-kick or during a set shot at goal. Therefore when the opposition is applying pressure it is implied that the ball is in motion. Thereby, the observed team's attacking chains may be comprised of handballs and fast movement patterns (i.e. run and carry) that try to disrupt opposition defensive structures but consequently invite opposition pressure, potentially explaining the results. Overall, this study provides important information for practitioners in understanding the physical cost of applying high pressure on the opposition and by the opposition and may be used to inform training design. This would help training drills become more representative of match conditions involving opposition pressure and facilitate players in tolerating the fatigue associated with applying pressure.

While we have previously shown that the initial chain state effects the activity demands of AF players (Vella et al., 2020), this research looks to further and differentiate it by possession phase (attack/defence). Kick-ins are a relatively structured scenario in AF (Taylor et al., 2020), and while a recent rule change (permitting immediate kick-ins) enables attacking teams to initiate play prior to defensive structures being organised, attacking teams may be susceptible to risky ball movement due to play being situated in close proximity of the opposition's goals. Therefore, HSR outputs may be reduced as attacking teams create congestion around the ball in order to reduce the risk of the opposition scoring in case of a turnover. Moreover, the present findings demonstrated that TD was greater for teams defending kick-ins, compared to stoppages and intercepts. This may result from defensive formations, particularly in wider field zones (DM and AM), continually needing to re-position as the attacking team tries to spread the opposition and creating more avenues to goal. This study also demonstrated that irrespective of possession phase, when play initiated from a turnover TD and HSR outputs increased. A common offensive tactic in AF is to quickly spread following a turnover (Rennie et al., 2020), opposition players chase their opponents and therefore mirror the team that has the ball, potentially explaining the results of the present study. Lastly, during both attacking and defensive chains, when greater field territory was gained there was an increase in TD and HSR outputs. When the ball covers a greater number of field zones, players have to work harder in order to continually be involved in the play or additionally shift the defensive zones further up the field. Overall, these results demonstrate that the initial chain state and the spatial constraints during individual possession chains influences the activity demands of AF players.

While this study was the first study to examine the collective influence of initial chain state and technical skill involvements on the activity demands of players during attacking and defensive chains, some limitations should be considered before interpreting the results. Firstly, the player and match data analysed in this study is from a single team and season. As such, the findings reflect the cohort of players within the observed team and the tactical strategies implemented during the observation period. Furthermore, while this study analysed player involvements, future studies should incorporate and analyse skill-based match events that occur during various possession chains. This would provide further knowledge on how teams chose to move the ball (by either foot or hand) and consequently the activity demands associated with these tactical strategies. Likewise, future studies should investigate the activity demands associated with applying pressure within separate field locations (e.g. D50, DM, AM, F50). This would help build on the knowledge attained from this study and provide coaches with further tactical considerations around defensive pressure. Additionally, despite the small (trivial) standardised effects sizes shown in the results, readers should focus on the non-standardised effect (the estimate) as this often increases incrementally. For example, the effect of field territory gained is per m increased, so the actual difference between chains can be far greater than the value presented. Lastly, extension of this research over several seasons should be considered to establish more meaningful associations between the variables examined here to enhance the current knowledge on physical activity in AF during different match phases.

4.6 Conclusion

Our study demonstrated that initial chain state, field territory gained, player involvement, and the defensive pressure applied influences the activity demands of professional AF players during attacking and defensive possession chains. Greater field territory gained and chains initiated from a kick-in or turnover elicited the highest activity demands irrespective of possession phase. During attacking chains, activity demands increased with greater opposition pressure and when attacking players were directly involved in the chain. Additionally, players applying direct pressure on the opposition during defensive chains increased their physical outputs. The present findings enhance previous research by incorporating technical involvement information to explain the activity demands during possession chains. Additionally, the result of the present study can be used to inform training design so players are exposed to representative match conditions from both attacking and defensive aspects.

4.7 Practical Implications

- Coaches can design training drills that reflect the physical requirements of applying pressure on the opposition observed during match-play so that players become more equipped to handle the associated transient fatigue. Subsequently, players may become better able to sustain high levels of pressure on the opposition during defensive chains.
- Knowledge of physical activity associated with different team tactics can be used by coaches to strategically and situationally control the speed of the game. For example, coaches can speed the game up by using direct ball movements, while alternatively designing tactics that utilise more frequent passes which enable their team to slow the game down.
- By segmenting time-motion data into individual possession chains, the specific behaviours of players during differences phases of play can be identified. For example, coaches can identify the players running the hardest to be involved in the play during attacking chains or to apply pressure on the opposition during defensive chains.

4.8 Acknowledgements

The authors have no conflicts of interest to declare

Chapter Five

Thesis summary, contributions and recommendations

5.1 Thesis summary and contribution

This thesis aimed to address a gap in the literature by linking and integrating information across physical, technical and tactical constructs of match-play. Furthermore, this thesis examined the game through individual possession chains rather than by quarter, half, or whole match analysis to achieve a more granular approach to what influences the activity demands of AF players. Study one observed the effect of key in-game contextual factors such as possession phase, initial chain state and starting field position on the activity demands of players. Study two then built on this initial work by including key technical constructs of match-play such as the direct involvement of players and opposition within chains specific to attacking and defensive phases of play. Overall, this thesis demonstrated that activity demands of AF players are influenced by the technical and tactical in-game factors occurring during different phases of play and highlighted the significance of integrated data analysis. The findings of this thesis can be used by coaches and sports practitioners to guide training design so drills are more representative of match requirements and additionally inform tactical strategies to be used during match-play.

The findings of this thesis enhance current understandings of the activity demands of AF match-play. While previous research reported on the activity demands associated with whole, quarter, and peak periods of play, this thesis analysed each individual possession chain, comprised of various field locations, initial chain states, and phases of play. This, in comparison to previous studies, provides important information on the activity demands associated with various tactical strategies. For example, teams looking to implement fast ball movement tactics following an intercept now know the relative activity demands associated with this tactic which can help guide future training and tactical strategy design. Additionally, by segmenting time-motion data into individual possession chains, compared to quarter, half or whole match analyses, coaches can analyse the behaviours of individual players during different phases of play and tactical scenarios. This deeper level of match physical analysis had previously not been available to coaches. Furthermore, this study was the first to report on the physical demands associated with applying pressure to the opposition. This provides coaches with information that can be used in training drills aiming to enhance the physical capabilities of their players during defensive chains, as well as being used for tactical considerations of when and how long to apply greater periods of pressure. Subsequently, players may become more equipped to handle the associated fatigue of applying pressure and therefore sustain higher levels of defensive pressure during competitive matches. Lastly, this thesis demonstrated the greater activity demands of a more direct style of play, compared to chains that involved a greater number of players touching the ball. Coaches may use this information to strategically and situationally control the speed of the match in order to retain possession and best optimise scoring opportunities.

5.2 Direction for future research

Future studies looking to enhance the understandings of activity demands during AF match-play using individual possession chains, should expand on this thesis by examining a greater cohort of players that spans multiple teams and seasons. By adding this depth to the data it is likely that the influence of a team's tactical or technical approach, or any changes in how the game is played across multiple season will be reduced. Moreover, future research should examine a greater number of movement metrics (e.g. accelerations/decelerations) and the count of specific skill-based match events occurring during possession chain (i.e. kicks or handballs). Inclusion of additional movement metrics may provide greater knowledge of the activity demands associated with various in-game scenarios and expand on the findings of this thesis. Additionally, by examining skill-based match events within individual possession chains coaches will have a more in-depth analysis of the associated activity demands of specific ball movement strategies. Lastly, future research should examine the influence of contextual factors and events occurring during possession chains on positional specific activity demands. This will provide a greater understanding of the activity demands associated with various positional groups during both different phases of play and tactical strategies.

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