

ABSTRACT

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Using the spatiotemporal characteristics of players, the primary aim of this study was to determine whether differences in collective team behaviour exist in Australian Rules football during different phases of match play. The secondary aim was to determine the extent to which collective team behaviour differed between competing teams and match half. Data was collected via 10 Hz global positioning system devices from a professional club during a 2 x 20 min, 15-v-15-match simulation drill. Five spatiotemporal variables from each team (x centroid, y centroid, length, width, and surface area) were collected and analysed during offensive, defensive, and contested phases. A multivariate analysis of variance comparing phase of match play (offensive, defensive, contested), Team (A & B), and Half (1 & 2) revealed that x -axis centroid and y -axis centroid showed considerable variation during all phases of match play. Length, width, and surface area were typically greater during the offensive phase comparative to defensive and contested phases. Clear differences were observed between teams with large differences recorded for length, width, and surface area during all phases of match play. Spatiotemporal variables that describe collective team behaviour can be used to understand team tactics and styles of play.

Key Words: Performance analysis, Tactics, Style of play

Commented [ja1]: Can change to this appease Reviewer 2 (Carl). He wanted more suggestive wording given the limited sample size. Can swap 'can' with 'may'.

Otherwise, no other comments about the abstract.

INTRODUCTION

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22 Research into the tactics or playing styles of invasion sport teams has typically been
23 undertaken using notational analysis. This method involves the recording of discrete actions
24 by players and teams (i.e., number of passes, possession, turnovers) in a sequential order
25 (Hughes and Franks, 2005; Lago, 2009; Liu, Gomez, Lago-Penas, & Sampaio, 2015;
26 Vogelbein, Nopp, & Hokelmann, 2014). Whilst useful in determining subsequent features of
27 team tactics or styles of play, this approach potentially underestimates the complexity of
28 invasion sports by disregarding broader contextual information, such as player positioning in
29 relation to teammates and opponents (Duarte, Araujo, Correia, & Davids, 2012; Travassos,
30 Davids, Araújo, & Esteves, 2013; Vilar, Araujo, Davids, & Button, 2012).

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32 One reason behind a lack of progress in using such contextual information may be in
33 part due to the absence of accessible and reliable data (Memmert, Lemmink, & Sampaio,
34 2017). The advent of player tracking technologies has allowed for increased access to
35 spatiotemporal data in training and matches. More recently, researchers have used this data to
36 generate a range of variables that determine how teams position themselves across a field of
37 play (Clemente, Couceiro, Martins, & Mendes, 2013a; Clemente, Couceiro, Martins, Mendes,
38 & Figueiredo, 2013b; Frencken, Lemmink, Delleman, & Visscher, 2011). Common examples
39 include: team centroid, which has been measured longitudinally, laterally, or radially
40 (Clemente, et al., 2013a), team surface area (Castellano, Álvarez, Figueira, Coutinho, &
41 Sampaio, 2013; Clemente, et al., 2013b; Clemente, Couceiro, Martins, Mendes, & Figueiredo,
42 2013c; Frencken, et al., 2011), and team length and width (Castellano, et al., 2013; Castellano
43 and Casamichana, 2015; Clemente, et al., 2013b; Clemente, et al., 2013c; Folgado, Lemmink,
44 Frencken, & Sampaio, 2014). The expression and interaction of these variables in different
match contexts can then be used to define and understand collective team behaviour.

45 Such information has been used to inform team tactics or styles of play (Clemente, et
46 al., 2013a; Clemente, et al., 2013c; Folgado, et al., 2014). In football, the team *x*-axis
47 (longitudinal) centroid has been used to determine that teams are positioned higher up the field
48 during home games when compared to away games (Bialkowski, Lucey, Carr, Yue, &
49 Matthews, 2014) and in the second half compared to the first half (Clemente, et al., 2013b).
50 Irrespective of match context, teams tend to maintain an overall position behind the centre of
51 the field, thereby preserving a level of ‘defensive stability’ (Castellano, et al., 2013; Clemente,
52 et al., 2013b; Clemente, et al., 2013c; Vilar, Araújo, Davids, & Bar-Yam, 2013). Other football
53 research has revealed that the surface area of experienced teams was greater compared to less
54 experienced teams (Olthof, Frencken, & Lemmink, 2015) and values decreased throughout the
55 match when comparing the first and second half (Clemente, et al., 2013b). Further,
56 comparative to lower ranked counterparts, higher ranking teams generally use more width than
57 length by having more supporting players across the field than along it (Castellano and
58 Casamichana, 2015).

59 Invasion sports are often separated into different phases of match play, such as
60 offence and defence, which are typically dictated by ball possession (Clemente, et al., 2013c).
61 Simply, the aim in offence is to advance the ball along a playing surface to score a goal, whilst
62 the aim of defence is to prevent the opposition from achieving this same aim (Memmert, et al.,
63 2017). However, as offence and defence are concomitant a team cannot position players to
64 create more attacking options whilst maintaining players in supportive regions to preserve
65 defensive stability (Grehaigine, Bouthier, & David, 1997). As such, distinct differences in
66 player positioning may occur between phases due to the emerging requirements throughout a
67 match (Castellano, et al., 2013; Clemente, et al., 2013b; Clemente, et al., 2013c). It has been
68 suggested that during offence, teams generally aim to spread to opposition’s defending players
69 to create space (Vilar, et al., 2013). While during defence, players will generally aim to restrict

70 the area in which the opposition can attack in (Vilar, et al., 2013). Studies support this
 71 proposition with higher values of length, width, and surface area recorded during offence when
 72 compared to defence (Castellano, et al., 2013; Clemente, et al., 2013b; Clemente, et al., 2013c).
 73 Therefore, the amount of possession may influence the overall collective behaviour of teams
 74 (Castellano, et al., 2013; Clemente, et al., 2013b). Despite this, limited studies that have
 75 analysed collective team behaviour in invasion sports have compared between phases of match
 76 play (Castellano, et al., 2013; Clemente, et al., 2013b; Clemente, et al., 2013c). Those that have
 77 are limited to utilising junior players in a 7-a-side playing format (Clemente, et al., 2013c) or
 78 have not quantified the total amount of possession (Castellano, et al., 2013; Clemente, et al.,
 79 2013b). Furthermore, despite a body of research examining collective team behaviour in
 80 football, investigations into Australian Rules Football remain largely absent. Australian Rules
 81 football (AF) is a sport where teams compete on an oval shaped field (length = ~160 m, width
 82 = ~130 m) with 22 players in total, with 18 on the field and 4 on an interchange (Gray and
 83 Jenkins, 2010).

84 Determining collective team behaviour has become a central component of match
 85 analysis due to its influence on performance outcome (Mimmert, et al., 2017). Researchers
 86 have used this information to describe team tactics or game style when it forms repetitive
 87 patterns of play (Sampaio and Macas, 2012). For a more contextual understanding of collective
 88 team behaviour studies have separated different phases of match play (Clemente, et al., 2013c).
 89 Despite this, limited studies have demarcated between phases of play. Furthermore, no
 90 investigations in Australian Football (AF) have been reported. Therefore, using the
 91 spatiotemporal characteristics of players, the primary aim of this study was to determine
 92 whether differences in collective team behaviour exist in Australian Rules football during
 93 different phases of match play. The secondary aim was to determine the extent to which
 94 collective team behavior differed between competing teams and match half.

Commented [ja2]: Reviewer #1 asked for a better link to the next paragraph. Have to agree. We originally jumped straight into the AF sentence. I've moved it up now.

Commented [ja3]: Reviewer #1 also wanted a clear statement of contribution and study pertinence. Also justify the aims. Lines 85-91 are new. I feel this is a lot clearer now. While not necessary it should keep them happy.

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METHODS

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98 Data were collected from one training session with 30 male professional AF players (age 23.9
99 ± 4.3 ; height 188.0 ± 7.9 ; body mass 86.0 ± 9.4) recruited from a single team in the Australian
100 Football League (AFL) competition. Participants took part in a match simulation drill as part
101 of preseason training. All participants received information about the requirements of the study
102 via verbal and written communication, and provided their written consent to participate. The
103 Victoria University Ethics Committee approved the study.

104 Participants were randomly separated into two teams of 15 each, labeled Team A and
105 Team B for analysis purposes. The match simulation took place on an oval shaped ground
106 using dimensions 163.7 m x 129.8 m (length x width) with two 20-min halves and a 10-min
107 break between periods. Data for all participants were collected using 10 Hz GPS devices
108 (Catapult Optimeye S5, Catapult Innovations, Melbourne, Australia). The devices were housed
109 in a fitted harness on the upper back. Previous investigations have assessed the validity and
110 reliability of these devices (Johnston, Watsford, Kelly, Pine, & Spurrs, 2014; Varley,
111 Fairweather, & Aughey, 2012).

112 Possession of the ball was determined via video observation and analysed to the
113 nearest decisecond by the first author. The offensive phase was recorded when a team first
114 gained possession of the ball and maintained it for at least a second and ended when the
115 opposing team gained possession of the ball for at least a second or there was a stoppage in
116 play (i.e., the team scored or the ball went out of bounds) (Yue, Broich, Seifriz, & Mester,
117 2008). Using the same conditions, the defensive phase was recorded when the opposing team
118 had possession of the ball (Yue, et al., 2008). If neither team had possession of the ball (i.e.,
119 when the officiating umpire returned the ball to play) the phase was considered to be in

Commented [ja4]: Reviewer #2 asked how the groups were selected. I'm not sure but it looked even.

120 'contest' until a team gained possession of the ball for at least a second. All periods were the
121 ball was out of play (e.g. break between periods of play, ball out of play, celebration after
122 goals) were excluding from the investigation.

Commented [ja5]: Reviewer #1 wanted to know if periods were excluded. Easy addition.

123 Spatiotemporal characteristics of participants recorded from the GPS units were
124 exported in raw 10 Hz format. Each file contained a global time stamp and calibrated location
125 (x - and y - location). The centre of the ground was signified as 0, 0. Each participant's file
126 consisted of approximately 33,000 data points including time and location. Spatiotemporal
127 data were then synchronised with ball possession using the respective global time stamps. This
128 was established using the initial point when the two widest players converged prior to start of
129 each quarter. Five variables (Figure 1) were derived from the data to describe collective team
130 behaviour. First, team centroid was calculated as the mean (x , y) position of all players on the
131 field of one team (Frencken, et al., 2011). Two measures were derived from the centroid
132 position. These were the distance in the x -axis centroid (m) and the distance in the y -axis
133 centroid (m) (Frencken, et al., 2011). The team surface area of each team was calculated as the
134 total space (m) covered by a single team, referred to as a convex hull (Frencken, et al., 2011).
135 Team length was measured as the distance between the most forward and most backward
136 player in the x -axis (m) and team width was defined as the distance between the two most
137 lateral players on the ground in the y -axis (m) (Frencken, et al., 2011). These variables were
138 assessed during offence, defence, and contested phases of match play and during first and
139 second halves. This was processed using the computational package Python version 3.2 with
140 *Spyder*, which is part of the Anaconda software suite (www.python.org).

Commented [ja6]: Reviewer #1 asked how

141

142 **Statistical Analyses**

143 Comparison of team x -axis centroid, y -axis centroid, length, width, and surface area were
144 assessed between phase of match play (3 levels: Offence, Defence, Contest), teams (2 levels:

145 Team A & Team B), and half (2 levels: Half 1 & Half 2), via a multivariate analysis of variance
146 (MANOVA). Homogeneity was analysed using the Levene Test, which resulted in a lack of
147 uniformity between phases of match play. The F test was used to combat homogeneity
148 violations due to the fact the total number of samples in each group was essentially equal
149 (Vincent, 1999). Due to the non-homogeneity of the time series data, the Central Limit
150 Theorem was considered, which allowed the assumption of normality to be made (Akritas,
151 2004). Cohen's conventions for effect size (d) were assessed, where 0.2, 0.5, and 0.8 are
152 considered as small, medium and large, respectively (Cohen, 1988). Statistical calculations
153 were determined using StatPlus™ (AnalystSoft, Alexandria, VA, USA) with significance set
154 at $p < 0.05$.

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RESULTS

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158 Between phase comparison for each team for the first and second half is displayed in Figure
159 2. Between team comparison for the first and second half is presented in Figure 3. The x -axis
160 centroid for Team B displaying possession throughout the match is displayed in Figure 4. The
161 amount of possession for the first and second half is shown in Table 1.

162

163

**** INSERT FIGURE 1 NEAR HERE ****

164

165 **Between**-phase analysis for the x -axis centroid was mixed, as Team B was positioned
166 higher up the field during the offensive phase when compared to the defensive phase in both
167 the first half (ES = 0.50, 90% CI = 0.46 – 0.50) and second half (ES = 1.06, 90% CI = 1.03 –
168 1.10). While in the first half Team A was positioned closer to their defensive end when
169 comparing the offensive phase to the defensive phase (ES = -0.65, 90% CI = -0.69 – -0.61).

Commented [ja7]: Effect sizes and Confidence intervals at 90% were required for each finding.

Makes this section very hard to read and quite long.

This paragraph is just for figure 2. There's 60 potential findings (3 phases x 2 teams x 5 metrics x 2 halves). I've only reported on medium/large effect sizes.

170 The y-axis centroid indicated both Team A () and Team B () had players situated to the right
 171 hand side of the field during offence when compared to defence in the first half. Length was
 172 greater during the offensive phase when compared to the defensive phase for Team B in the
 173 first half (ES = 0.77, 90% CI = 0.72 – 0.82) and Team A in the second half (ES = 0.94, 90%
 174 CI = 0.91 – 0.98). Length during the offensive phase was less when compared to the contested
 175 phase for Team A (ES = 0.57, 90% CI = -0.63 – -0.51) and Team B (ES = -0.90, 90% CI = -
 176 0.96 – -0.84) during the second half. Length was also smaller during the defensive phase when
 177 compared to the contested phase for Team A (ES = -0.65, 90% CI = -0.69 – -0.60) and Team
 178 B (ES = -0.77, 90% CI = -0.82 – -0.72) during the first half and for Team A (ES = -1.05, 90%
 179 CI = -1.12 – -0.99) and for Team B (ES = -1, 90% CI = -1.07 – -0.94) during the second half.
 180 Width was greater during offence when compared to defence for Team A during the first half
 181 (ES = 0.65, 90% CI = 0.62 – 0.69) and second half (ES = 1.3, 90% CI = 1.26 – 1.34). Team B
 182 also displayed greater width during offence when compared to defence during the first half
 183 (ES = 0.55, 90% CI = 0.51 – 0.58) the second half (ES = 0.94, 90% CI = 0.91 – 0.98). Width
 184 was greater in offence than contest for Team B in the first half (ES = 1.21, 90% CI = 1.16 –
 185 1.27) and second half (ES = 1.64, 90% CI = 1.57 – 1.70). Team A displayed less width during
 186 the defensive phase when compared to the contested phase in the first half (ES = -0.59, 90%
 187 CI = -0.64 – -0.54) and second half (ES = -1.11, 90% CI = -1.17 – -1.05). In contrast, Team B
 188 had greater width during defence when compared to contest in the first half (ES = 1.01, 90%
 189 CI = 0.96 – 1.06) and second half (ES = 1.18, 90% CI = 1.11 – 1.24). Surface area was greater
 190 during the offensive phase when compared to ~~than~~ the defensive phase for Team A in the
 191 second half (ES = 0.70, 90% CI = 0.66 – 0.73) and for Team B in the first half (ES = 1.02,
 192 90% CI = 0.98 – 1.06) and second half (ES = 0.91, 90% CI = 0.88 – 0.95). Surface area was
 193 also greater during the offensive phase compared to the contested phase for Team A in the first
 194 half (ES = 0.90, 90% CI = 0.84 – 0.97) and second half (ES = 1.16, 90% CI = 1.10 – 1.22) and

195 for Team B in the first half (ES = 1.32, 90% CI = 1.27 – 1.37) and second half (ES = 1.42,
 196 90% CI = 1.36 - 1.49). When comparing defensive to contested phases, the surface area was
 197 greater for Team A during the first half (ES = 0.64, 90% CI = 0.57 – 0.70) and second half (ES
 198 = 0.56, 90% CI = 0.51 – 0.61) and for Team B during the first (ES = 0.54, 90% CI = 0.49 –
 199 0.59) and second half (ES = 0.71, 90% CI = 0.65 – 0.77).

200

201 *** INSERT FIGURE 2 NEAR HERE***

202

203 Between-team analysis displayed the x-axis centroid of Team B (Figure 3) as higher
 204 up the field in all phases of match play for the first half when compared to Team A.
 205 Contrastingly, in the second half, Team A was higher up the field in all phases of play when
 206 compared to Team B. Except for width during the contested phase, Team B had greater values
 207 in length, width, and surface area during all phases of play.

208

209 ***INSERT FIGURE 3 NEAR HERE***

210

211 Possession data displayed that Team B had greater possession of the ball in the first
 212 half, while Team A had greater possession of the ball in the second half.

213

214 ***INSERT FIGURE 4 NEAR HERE***

215

216 ***INSERT TABLE 1 NEAR HERE***

217

218 **DISCUSSION**

219

Commented [ja8]: I haven't added in ES and CI for these (between team analysis). Hopefully get away with just doing it for between phase analysis.

If necessary it will blow out this paragraph too. I'd have to put in another 24 separate effect sizes and confidence intervals.

220 This is the first study to describe collective team behaviour in AF teams during different phases
221 of match play. The central finding was that collective team behaviour was influenced by match
222 phase. The x -axis centroid and y -axis centroid recorded large variations during all phases of
223 match play. Length, width, and surface area were typically greater during offence when
224 compared to defence and contest. Between-team analysis established differences in collective
225 team behaviour with Team B recording greater values in length, width, and surface area during
226 all phases of match play.

227 In the first half, Team A's x -axis centroid recorded the team in their defensive half
228 during all phases of match play. This may suggest that they were displaying more conservative
229 team behaviour by preserving players to defend their goal. However, the x -axis centroid during
230 offence was further behind their x -axis centroid in defence. This would indicate that the players
231 moved towards their defensive end during attacking sequences, which would be
232 counterintuitive. Therefore, this finding may be associated with where possession was gained
233 or lost. If possession were gained in the defensive half, it would mean attacking sequences
234 commenced further away from the opposition's goal. As subsequent attacking sequences
235 moved towards their scoring end a turnover of possession would mean their centroid in defence
236 is higher up the field of play. This may be associated with the possession rate as Team B had
237 more possession of the ball, which would require Team A to defend more often and more than
238 likely in their defensive end. In the second half, Team A had greater possession of the ball and
239 their x -axis centroid was considerably closer to their goal in all phases of match play. As a
240 result, Team B's x -axis centroid signified that they defended closer to their goal in both
241 contested and defensive phases. However, Team B did maintain a positive x -axis centroid
242 during offence throughout the whole match. The y -axis centroid indicated that both teams
243 attacked from the right hand side of the field in the first half. Throughout the match, Team B
244 displayed more expansive behaviour compared to Team A regardless of match phase or team

245 possession. Specifically, Team B recorded consistently greater values in length, width, and
246 surface area during all phases of match play, apart from width during the contested phase. This
247 type of behaviour may be associated with players aiming to spread the opposition defending
248 players to create a greater effective playing space, which allows for an easier passage of the
249 ball (Vilar, et al., 2013).

250 Research undertaken in football suggests that overall; teams employ more
251 conservative team behaviour by positioning players closer to their own goal (Clemente, et al.,
252 2013b; Clemente, et al., 2013c; Vilar, et al., 2013). Results from this study indicate that AF
253 teams display large variations in both positive and negative overall positioning. Whilst a
254 formal comparison between sports has not been made here, it appears AF teams may be more
255 willing to collectively move higher up the field if the ball is in their attacking end and
256 conversely, reposition deeper towards their defensive end when the opposition has possession
257 of the ball. Investigations in soccer have found that teams play with more length, width, and
258 surface area in offence compared to defence (Clemente, et al., 2013c). Correspondingly, this
259 study suggests AF teams have typically greater values in offence compared to defence.
260 Furthermore, both teams had a greater surface area in both offence and defence when compared
261 to contest. This may indicate that both teams tried to constrict space when the ball was in
262 dispute or be a defensive mechanism to close down space quickly if the opposition gained
263 possession of the ball.

264 Whilst invasion sport teams will engage certain behaviours in order to achieve
265 success, resulting player movement is constantly influenced by athletes adapting to contextual
266 variables (i.e., match status, opposition team tactics, time, and where ball possession takes
267 place) (Castellano, et al., 2013; Rein and Memmert, 2016). Therefore, it is difficult to
268 differentiate if collective team behaviour is a result of a preconceived team tactic, due to
269 emerging contextual variables, or a combination of both (Rein and Memmert, 2016). This

270 conundrum is highlighted through research in football which established that when playing
271 against lower ranked teams within the same league, higher values of length, width, and surface
272 area were found during offence when compared to defence (Castellano, et al., 2013). However,
273 this finding was reversed when playing against higher ranked teams, with smaller values of
274 length, width, and surface area during offence compared to defence (Castellano, et al., 2013).
275 Nonetheless, researchers analysing an entire season of first and second division Spanish soccer
276 found that length in top ranking teams in first division was different to length in top ranking
277 teams in the second division league (Castellano and Casamichana, 2015). This finding
278 indicates a different strategy to play with more length when comparing first division and
279 second division teams. Furthermore, longitudinal investigations in soccer also found that teams
280 in the English Premier League may employ more conservative team behaviour by positioning
281 players closer to their own goal during away games when compared to home games
282 (Bialkowski, et al., 2014).

283 Limitations surrounding sample size and match reproducibility in this study should
284 be considered when interpreting the results. This study analysed collective team behavior from
285 one match in an out of season match. Additional data from multiple matches during a
286 competitive season are required to ensure collective team behavior in AF is consistent with
287 this research. The authors also recommend future studies incorporate contextual variables
288 including phase of play and position on the field.

289 Quantifying collective team behaviour on a longitudinal basis, whilst considering
290 contextual variables, will assist in uncovering repeated patterns in player movement. This then
291 provides sporting organisations with an enhanced understanding of teams tactics or styles of
292 play, which can assist in improving performance. Practically, this information will assist in
293 developing specific training regimes to promote desired tactical structures. Coaches can use
294 this to reinforce how players should position themselves in various phases of play. This

Commented [ja9]: Both reviewers hinted at limitations. Reviewer 1 wanted a paragraph on this and future recommendations. Don't mind this though as it will be a good lead into study 2.

295 information can also be used in gaining a competitive advantage by exploiting any perceived
296 inefficiencies in the opposition's style of play. Specifically, whilst defending, players may
297 position themselves higher up the field to minimise the space the attacking team can operate
298 in. This may increase the likelihood of regaining possession or constraining offensive ball
299 movement. However, this tactic may also create unguarded defensive space closer towards the
300 opposition's goal, which may leave the team susceptible to attacking sequences that are able
301 to penetrate the defending players. Conversely, if players maintain defensive stability by
302 occupying space closer to goal, this may create space higher up the field. Attacking teams may
303 utilise this space and employ a higher possession style of play to minimise potential turnovers.

Commented [ja10]: Reviewer #1 wanted specificity surrounding practical applications. Could maybe trim this down a bit...

306 CONCLUSION

307
308 The results from this study describe the collective team behaviour of AF teams during various
309 phases of match play. The main findings advocate that collective team behaviour is influenced
310 by match phase. The *x*-axis centroid and *y*-axis centroid recorded large variations during all
311 phases of match play. Length, width, and surface area were typically greater during offence
312 when compared to defensive and contested phases. Clear differences were observed between
313 teams with large differences recorded for length, width, and surface area during all phases of
314 match play. Spatiotemporal variables that describe collective team behaviour can be used to
315 understand team tactics and styles of play.

317 DISCLOSURE OF INTEREST

318
319 The authors report no conflicts of interest.

320

321

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