1	The influence of physical fitness on the response to intense exercise periods during						
2	female Australian football match-play						
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27 Abstract

28 **Objective:** To investigate the influence of physical fitness on peak periods of match-play.

Methods: Forty-three female Australian footballers from three teams wore global positioning system units in matches during one competitive season. The Yo-Yo Intermittent Recovery Test (Level 1) was conducted as an estimate of physical fitness. One-, two-, three-, four- and five-minute rolling periods were analysed in order to determine the "peak" and "subsequent" periods during match-play.

33 **Results:** Midfielders covered greater distances during peak periods than half-line players (Effect size, 34 ES range = 0.33-0.86; likelihood $\geq 76\%$). No meaningful differences were reported between positional groups for high-speed distances during the peak periods, with the exception of half-liners covering 35 greater distance during the 1-minute period (ES = 0.38; likelihood = 80%). Higher fitness players 36 covered greater peak total and high-speed (ES range = 0.70-1.16; likelihood $\ge 94\%$) distances than lower 37 38 fitness players, irrespective of position. Higher fitness midfielders covered greater high-speed distances during the 1 to 3-minute subsequent periods than lower fitness midfielders (ES range = 0.46-0.71; 39 40 likelihood $\geq 81\%$). Half-liners with greater Yo-Yo performances covered greater relative total and low-41 speed (ES range = 0.47-0.70; likelihood \geq 76%) distances during the subsequent periods than lower 42 fitness players.

43 Conclusion: Developing physical fitness may enable greater peak and subsequent period performances
44 and improve players' abilities to maintain higher average match intensities.

Keywords: Global positioning systems; work rate; intense periods; positional differences; transient
reductions; Yo-Yo

47 Introduction

48 Understanding the demands of match-play has been central to training prescription in team sport athletes (Gabbett et al. 2009). Research commonly reports the average distances covered during matches 49 (Dawson et al. 2004; Varley et al. 2014). However, given the stochastic nature of team sports, the 50 51 fluctuations in running demands that regularly occur during match-play are less understood. The use of 52 global positioning system (GPS) technology has allowed scientists to detect transient reductions in running performance during team sport match-play (Aughey 2010; Coutts et al. 2010; Wisbey et al. 53 54 2010). Specifically, research has recently shown female Australian football (AF) midfielders and half-55 line players reduce overall running intensity and high-speed distances across match halves (Black et al. 2019). Despite the importance of understanding variations in running performance over the course of a 56 match, knowledge of peak running periods (Delaney et al. 2017a) is of equal importance to optimise 57 58 player preparedness for possible match situations, such as increasing high-speed running to create space 59 or beat an opposing player to the football.

60

61 To understand intense passages of play, studies have used rolling time scales to identify peak periods of high-intensity running throughout matches (Varley et al. 2012; Black et al. 2016). Using rolling 62 periods, research has reported reductions in running performance following the most intense match 63 64 periods in a number of team sports (Kempton et al. 2013; Black et al. 2016; Sparks et al. 2016). With 65 the exception of one study (Black et al. 2016), 5-min peak periods for total distance have been compared 66 with the subsequent 5-min period and the average match running intensity to measure transient reductions in physical performance (Mohr et al. 2003; Carling and Dupont 2011; Kempton et al. 2013). 67 However, recent research investigating duration-specific peak running periods in male AF and rugby 68 69 league found increases in running intensity as the duration of the rolling period decreased (Duthie et al. 2017; Delaney et al. 2017a). These findings show that 5-min epochs are not representative of true 70 maximal match intensity in team sports (Delaney et al. 2017a, 2017b). Furthermore, although 71 72 researchers have provided insight into peak exercise periods and player's responses to within match

73 fatigue, studies have not taken into account how physical fitness may influence this response.

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75 Several studies of team sport athletes have identified a relationship between physical fitness and match 76 running performance. In AF (Mooney et al. 2011) and soccer (Krustrup et al. 2005), Yo-Yo Intermittent 77 recovery test scores have been associated with greater total- and high-speed running distances during 78 match-play. However, female team-sport athletes consistently score lower on the Yo-Yo IR1 test 79 (Krustrup et al. 2005; Veale et al. 2010; Deprez et al. 2015; Black et al. 2018) and cover less high-speed 80 distance during competitive match-play (Wisbey et al. 2010; Black et al. 2018) than their male 81 counterparts. Therefore, peak running periods, specific to female field-sport athletes, require 82 investigation to further inform coaching practices and increase match preparedness. In addition, 83 research is yet to investigate the influence of fitness on duration-specific peak periods in highly intermittent, running-dominant team sports, such as AF or soccer. In order to understand the influence 84 85 of physical fitness on peak periods, and responses to peak periods of match-play, this study aimed to 86 (1) identify peak periods of varying durations in female AF and (2) determine whether better 87 performance on the Yo-Yo IR1 was associated with greater distances covered during the peak and 88 subsequent periods in female AF match-play.

89

90 Methodology

91 *Participants*

Forty-three players (age 24.3 \pm 5.5 yrs, height 167.4 \pm 4.3 cm, body mass 66.5 \pm 9.3 kg) from three Queensland Women's Australian Football League teams were recruited into this study. Two positional groups were analysed in this study and were further separated into high or low fitness groups based on their Yo-Yo IR1 score; midfielders (median split = 800 m; high fitness n = 11; Yo-Yo IR1 distance 950 \pm 62 m, low fitness n = 11; Yo-Yo IR1 distance 670 \pm 165 m) and half-line players (median split = 680 m; high fitness n = 10; Yo-Yo IR1 distance 800 \pm 95 m, low fitness n = 11; Yo-Yo IR1 distance 410 \pm 80 m). All participants completed two field sessions per week with their respective clubs during the 99 preseason. However, extra individual training sessions were not accounted for and if performed, these 100 would likely influence the physical fitness of individual players. Due to the small number of the half-101 backs and half-forwards these positions were pooled (Brewer et al. 2010) to represent the half-line 102 group. Prior to data collection, participants received an information sheet outlining the risks and benefits 103 of the study and written consent was obtained. The study was approved by the Australian Catholic 104 University's Human Research Ethics Committee (2016-27H).

105

106 Procedures

An observational cohort study was used to investigate the influence of physical fitness on the response to intense exercise periods in female AF match-play. Physical fitness was assessed using the Yo-Yo IR1 test and match running performances were measured using GPS units worn across one competitive season. Each positional group were divided into two subsets based on their final Yo-Yo score. Each match was analysed in rolling periods in order to compare the "peak", "subsequent" and "mean" periods during match-play for players with high and low fitness.

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During the final 2 weeks of preseason, players were required to complete the Yo-Yo IR1 to assess 114 physical fitness, with the total distance covered recorded as the Yo-Yo IR1 score. Players were 115 separated into four groups based on their positional groups and Yo-Yo IR1 performance. Specifically, 116 following the test both the midfield and half-line players were further divided into two subsets according 117 118 to their Yo-Yo IR1 performance using a median split (high/low fitness midfielders, high/low fitness half-liners). During testing, participants wore football boots and their normal training clothes; given 119 that some players were unfamiliar with the Yo-Yo IR1 test, the first two levels were incorporated into 120 the warm-up. The typical error of measurement for the Yo-Yo IR1 has been reported as 4.9% in female 121 122 athletes (Krustrup et al. 2003).

123

124 Each player's match activity profiles were recorded for each quarter during at least four (mean \pm SD: 5.1 ± 0.6 ; range: 4–6; total GPS files: 180) competitive matches across the 2016 competitive season. 125 Player movement was recorded using a S5 GPS unit (S5, Optimeye, Catapult Sports, Docklands, VIC, 126 127 Australia) sampling at 10 Hz worn in a customised vest positioned between the shoulder blades. These 128 10 Hz GPS units have reported greater validity and inter-unit reliability than 1 Hz and 5 Hz units 129 (Johnston et al. 2014). Data were downloaded onto a laptop and analysed using software provided by the manufacturer (Sprint 5.1.7, Catapult Sports, Docklands, VIC, Australia). All matches were played 130 131 at the same time of day (~1600 h). Activity profiles were determined by dividing movements into lowspeed (0-4.16 m.sec⁻¹), and high-speed (>4.16 m.sec⁻¹) bands as it has been recommended that speeds 132 of 15-16 km.hr⁻¹ should be used to define highspeed running in female team sport athletes (Bradley and 133 Vescovi 2015). Only active field time was included in analyses; data were removed for the time players 134 were rotated or interchanged off the field. 135

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137 As has been previously described (Black et al. 2016), the physical performance variables were arranged into 1-min rolling periods (Varley et al. 2012). Although 5-min epochs are commonly used to identify 138 peak match periods (Mohr et al. 2003; Sparks et al. 2016), individual files were separated into periods 139 of five different durations (1, 2, 3, 4 and 5-min). To measure transient reductions in performance, peak 140 141 periods were identified as the intervals with the maximum distance covered per minute (m.min⁻¹), for 142 each match. This period was then compared with the subsequent duration interval and the average match 143 intensity. Data were removed from the analysis if players were interchanged off the field or the match 144 quarter ended in the subsequent period. A total of 180 match files were included in the analysis (GPS 145 files n = 97 midfielders [45 high fitness, 52 low fitness]; GPS files n = 83 half-line players [high 49] fitness, 34 low fitness]). A sample size of 34 files per group was required to enable the detection of an 146 ES difference of > 0.30 (Hopkins et al. 2009). However, 155 peak periods were rem oved (72 [15%] 147 148 midfielders, 83 [20%] half-line players) from the analysis as players were interchanged off the field or 149 the match quarter ended in the subsequent period.

150

151 Statistical Analyses

152 Cohen's effect size (ES) statistic \pm 90% confidence intervals (CI) were used to determine the magnitude of differences between midfielders and half-line players. Differences between the peak, subsequent and 153 the average match demands were calculated. Furthermore, differences between high and low fitness 154 groups were also compared. The effect sizes were classified as substantially greater or lesser when there 155 was a \geq 75% likelihood of the effect being equal to or greater than the smallest worthwhile change 156 estimated as 0.2 x between-participants SD (small ES). Effect sizes of ≤0.2, 0.21-0.6, 0.61-1.2, 1.21-157 2.0, and >2.0 were considered trivial, small, moderate, large, and very large, respectively (Hopkins et 158 159 al. 2009). A custom Excel spreadsheet (Version 16, Microsoft, USA) was used to calculate ES, CI and likelihoods (Hopkins et al. 2009). 160

161

162 Results

Midfielders covered meaningfully greater distances on the Yo-Yo IR1 test than the half-line group (ES 163 $= 0.53 \pm 0.63$; Likelihood = likely probable, 80%). Greater average match relative total- and low-speed 164 165 distances were covered by the midfielders compared with the half-line players. Table 1 illustrates the 166 peak periods for midfield and half-line positional groups. No meaningful differences were reported between playing positions for high-speed distances during peak periods (ES ≤ 0.28 ; likelihood $\leq 65\%$) 167 with the exception of the 1-min period (ES = 0.38 ± 0.36 ; Likelihood = likely probable, 80%). As the 168 169 duration of the peak period increased, running intensity subsequently decreased (ES range = 0.37 - 1.31; likelihood \geq 77%). 170

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Insert Table 1 here

173

Figures 1 and 2 illustrate the differences among peak, subsequent and average running intensities forthe high and low fitness players. No meaningful differences were reported between high and low fitness

176	midfielders, irrespective of period, for low-speed distances covered (ES ≤ 0.37 ; likelihood $\leq 74\%$).
177	Higher fitness midfielders covered greater high-speed distances than the lower fitness players during
178	the subsequent 1-, 2- and 3-min periods (ES = 0.57 ± 0.61 ; likelihood $\ge 82\%$). Higher fitness half-line
179	players covered greater relative total- (ES range = $0.89-1.22$; likelihood $\ge 99\%$) and high-speed (ES
180	range = 0.70–1.16; likelihood \ge 94%) distances during all peak periods than lower fitness players.
181	Greater relative total (ES \ge 0.59 \pm 0.70; likelihood \ge 85%) and low-speed (ES \ge 0.47 \pm 0.74; likelihood
182	\geq 76%) distances were covered by the higher fitness half-liners than the lower fitness players in the
183	subsequent 2-, 3- and 5-min periods. Higher fitness half-line players reduced high-speed running below
184	the match average during all subsequent periods (ES $\ge 0.43 \pm 0.84$; likelihood $\ge 80\%$).

Insert Figure 1 here

Insert Figure 2 here

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189 Discussion

190 This is the first study to identify true peak periods, of varying durations during female AF match-play. 191 Moreover, this study compared the effect of physical fitness on the response to short periods of high-192 intensity activity. True peak periods, based on maximal distances covered per minute, were identified 193 across a number of duration-specific periods. In contrast to male AF players (Delaney et al. 2017a), these results demonstrate that midfielders exhibit greater peak periods, irrespective of period duration, 194 195 than half-line players. Additionally, greater Yo-Yo performers covered greater relative total and high-196 speed distances in all peak periods than low Yo-Yo performers. The current findings highlight the 197 importance of developing physical fitness and identify intense exercise periods that players will be 198 exposed to during match-play.

199

200 Midfielders covered greater distances, during peak periods of play than the half-line players. However, these differences were largely explained by distances covered at low-speed. Additionally, midfielders 201 202 reported greater fitness levels and, similar to previous research, greater average match demands 203 (Dawson et al. 2004) than the half-line players. Collectively, these findings suggest that players with 204 lower fitness levels may be selected for positions that are less physically demanding. Notwithstanding, 205 both positional groups are exposed to intense passages of play during female AF matches (Table 1). 206 Interestingly, as the discrete period duration increased, the difference between midfield and half-line 207 peak running intensities also increased. Moreover, in accordance with previous research (Delaney et al. 208 2017a), half-line players covered greater high-speed distances during the 1-min peak period than the 209 midfielders. These findings suggest that half-line players should be exposed to shorter duration peak periods $(1-2 \min)$ during training as they may be more representative of match situations. Nevertheless, 210 211 with the exception of the 1-min period, high-speed distances were comparable across positional groups, 212 which emphasises the importance of increasing high-intensity activity during intense match stages as for female footballers, irrespective of playing position. 213

214

While fluctuations in match running intensity across female AF matches have been previously reported 215 (Black et al. 2017a), our results highlight the most demanding fluctuations of match-play (Table 1). The 216 217 greatest "peak" period of matchplay performed by an individual player consisted of 212 m covered, 122 218 m at low-speed and 90 m covered at highspeed. In agreement with previous research (Delaney et al. 219 2017a), as the period duration increased (~1 min), running intensity was reduced. Nevertheless, 220 irrespective of the period duration, players are required to exhibit significantly greater running 221 intensities compared with the match average during these short epochs. Therefore, the results 222 demonstrate duration-specific running intensities that can be used to develop "worst-case scenario" 223 training drills (Black and Gabbett 2015; Delaney et al. 2017a) specific to female footballers. While 224 running intensities may be influenced by contextual factors such as game outcome (Lago et al. 2010), 225 match score (Sullivan et al. 2014), opposition rank (Hulin and Gabbett 2015) and playing strategy, these 226 were not accounted for in this study and require further research.

227

228 Higher Yo-Yo IR1 performers covered greater relative total and high-speed distances during all peak periods compared with low Yo-Yo performers, irrespective of position. These findings demonstrate that 229 superior fitness enables female footballers to increase high-speed running during intense match periods 230 which, although speculative, may lead to a greater ability to (1) lead for the football, (2) beat their 231 opponent to a contest, or (3) evade their opponent by running to space to become a passing option for 232 their teammate. Furthermore, as research has identified relationships between Yo-Yo performance, 233 high-intensity match running and skill involvements (Mooney et al. 2011); and peak exercise periods 234 235 are associated with greater skill involvements in male AF players (Black et al. 2016), superior Yo-Yo performance may increase female footballers' ability to gain possession of the football during peak 236 237 periods.

238

Higher fitness midfielders covered greater high-speed distances during the subsequent 1-, 2- and 3-min 239 240 periods compared with lower fitness midfielders. Given that the Yo-Yo IR1 is an assessment of high-241 intensity intermittent running ability (Krustrup et al. 2005), it is not surprising that higher Yo-Yo 242 performers were protected from match-related fatigue (Kempton et al. 2013) following the peak match periods. While higher fitness midfielders reduced high-intensity activity below their match average 243 244 during the subsequent 4- and 5-min period, high-speed distances were comparable with low fitness 245 players. Given that higher fitness players exhibited greater peak period and match intensities, it is 246 possible these players implemented a self-preservation strategy (Noakes et al. 2005; Tucker and Noakes 2009) during these subsequent periods and performed at the lowest intensity that the match allowed. 247

248

In contrast to the findings from mid-fielders, half-line players covered comparable high-speed distances 249 250 across fitness groups during the subsequent periods (Figure 2). Differences between high and low 251 fitness half-line players were explained by distances covered at low-speed. Although in disagreement 252 with previous research (Kempton et al. 2013; Black et al. 2016), a possible explanation may lie within the positional requirements of the half-line players. Male AF half-line positional players complete fewer skill involvements than midfielders (Dawson et al. 2004). Therefore, it is possible that following peak periods, high-intensity running is not demanded of half-line players as the football has been cleared from the attacking/defending zones.

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258 A limitation of this study is the relatively small number of players (three teams drawn from one state 259 competition) included in this analysis. Also, due to the small sample size of the full-line positional group (full backs/forwards and back/forward pockets), these data were excluded from the analysis. 260 Future research should aim to identify intense match periods in all teams competing in the national 261 262 female AF competition. Additionally, there are a number of confounders, such as individual player nutrition and match recovery strategies that were not accounted for and may have influenced running 263 performance. Furthermore, the Yo-Yo IR1 was only assessed once at the end of preseason; as such it is 264 265 possible that physical fitness may have improved or declined as the season progressed. Finally, work 266 rate does not equate to performance, therefore further research investigating the influence of peak periods on match running performance and skill efficiency in elite female AF players is warranted and 267 268 remains a future challenge.

269

270 Practical applications

The assessment of high-intensity running ability is important for female AF players, as superior Yo-Yo IR1 performance is linked with greater distances covered during peak and subsequent periods, of varying durations, and average match running intensities. Players with poorly developed physical fitness should be identified early to detect individual deficiencies and allow sufficient time for improvements. Additionally, coaches should expose all players to the "worst-case scenarios" during training to increase match preparedness. Small-sided games or high-intensity interval training, using peak running intensities relative to the drill duration, could be used to develop physical fitness and

- adequately prepare players for competition. However, these distances and intensities should be used as
- a starting point with training programs progressively increased to greater intensities.
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362 and low fitness midfielders; $^{\text{c}}$ denotes meaningful difference (ES = 0.50–0.62) between the subsequent period and match average.



Figure 2: Duration-specific peak and subsequent periods, and match averages for the higher fitness and lower fitness half-line players.

l: a large effect size difference (ES = 1.21-2.0) between high and low fitness half-line players; m: a moderate effect size (ES = 0.61-1.2) difference between

- high and low fitness half-line players; s: a small effect size (ES = 0.21–0.60) difference between high and low fitness half-line players; ^ denotes meaningful
- 367 difference (ES = 0.50-0.62) between the subsequent period and match average.

	Midfielders	Half-liners	% difference	ES CI	Likelihood
Average match demands					
Relative-distance (m.min ⁻¹)	109 (77-127)	94 (69-109)	18.7	1.06 ± 0.28	Almost certainly
Low-Speed distance (m.min ⁻¹)	95 (69-109)	82 (60-105)	18.7	1.15 ± 0.26	Almost certainly
High-speed distance (m.min ⁻¹)	14 (7-30)	13 (6-25)	19.7	0.19 ± 0.32	Trivial
1-minute Period					
Relative-distance (m.min ⁻¹)	178 (148-211)	173 (236-212)	3.1	0.33 ± 0.35	Possible
Low-Speed distance (m.min ⁻¹)	132 (59-180)	116 (61-167)	13.9	0.6 ± 0.35	Very likely
High-speed distance (m.min ⁻¹)	46 (0-109)	57 (0-130)	-18.9	-0.38 ± 0.36	Likely, probable
2-minute period					
Relative-distance (m.min ⁻¹)	156 (134-184)***	148 (120-172)***	5.7	0.64 ± 0.35	Very likely
Low-Speed distance (m.min ⁻¹)	127 (97-167)	114 (83-153)	11.1	0.72 ± 0.34	Almost certainly
High-speed distance $(m.min^{-1})$	29 (4-60)**	33 (0-66)**	13	-0.28 ± 0.37	Possible
3-minute period					
Relative-distance (m.min ⁻¹)	147 (125-176)*	136 (108-155)**	8.3	0.81 ± 0.35	Almost certainly
Low-Speed distance (m.min ⁻¹)	122 (90-149)	108 (84-128)*	13.1	0.99 ± 0.33	Almost certainly
High-speed distance (m.min ⁻¹)	25 (4-52)	28 (5-57)*	-10.4	-0.24 ± 0.38	Possible
4-minute period					
Relative-distance (m.min ⁻¹)	141 (121-167)*	130 (102-155)*	8.7	0.82 ± 0.36	Almost certainly
Low-Speed distance (m.min ⁻¹)	119 (93-147)	107 (83-141)*	11.2	0.87 ± 0.34	Almost certainly
High-speed distance (m.min ⁻¹)	22 (5-43)	23 (4-53)	3.3	-0.07 ± 0.38	Trivial
5-minute period					
Relative-distance (m.min ⁻¹)	137 (115-158)	125 (98-156)	9.3	0.86 ± 0.37	Almost certainly
Low-Speed distance (m.min ⁻¹)	116 (83-141)	103 (85-140)	12.6	0.92 ± 0.35	Almost certainly
High-speed distance (m.min ⁻¹)	21 (5-41)	22 (5-49)	-5.8	-0.14 ± 0.39	Trivial

368 Table 1. Positional comparisons of running demands during competition

369 Data reported as mean (range); *denotes small ES (0.43-0.47) difference from previous duration-specific period; **denotes moderate ES (0.68-0.90) difference

370 from previous duration-specific period; ***denotes large ES (1.21-1.31) difference from previous duration-specific period