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Article · August 2020

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The Relationship of Aerobic Endurance and Linear Speed on Repeat Sprint Ability Performance in Female International Footballers

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Received July 7, 2020; Revised August 18, 2020; Accepted August 28, 2020

Cite This Paper in the following Citation Styles

(a): [1] Brian Doyle, Declan Browne, Dan Horan, "The Relationship of Aerobic Endurance and Linear Speed on Repeat Sprint Ability Performance in Female International Footballers," *International Journal of Human Movement and Sports Sciences*, Vol. 8, No. 4, pp. 147 - 153, 2020. DOI: 10.13189/saj.2020.080407.

(b): Brian Doyle, Declan Browne, Dan Horan (2020). *The Relationship of Aerobic Endurance and Linear Speed on Repeat Sprint Ability Performance in Female International Footballers*. *International Journal of Human Movement and Sports Sciences*, 8(4), 147 - 153. DOI: 10.13189/saj.2020.080407.

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Abstract The aim of this study was to investigate the relationship between aerobic endurance and linear speed on repeat sprint ability performance in female international footballers. Twenty-five female international football players completed 10-m, 20-m, 30-m linear speed, repeat sprint ability (RSA) and yo-yo intermittent recovery, level 1 tests. Pearson's product correlation (r) was used to assess the relationship between 10-m, 20-m and 30-m sprint times (S10-m, S20-m, S30-m) sprint time on the first trial of the repeated sprint test (RST1) and yo - yo intermittent recovery test, level 1 (YYIR1) with total repeated sprint time (RSTT). Linear regressions were used to describe the relationship between the dependent variable (RSTT) and independent variables (S10-m, S20-m, S30-m, RST1 and YYIR1). Pearson's correlation analysis indicated a large negative correlation between RSTT and YYIR1 performance ($r = -0.58$, $P = .002$), a very large significant relationship was established between S10-m and S20-m whilst an almost perfect relationship was present for S30-m and RST1. The results of the linear regression proved the independent variable RST1 explained 85% (adjusted R^2) of the variation in RSTT scores. S10-m, S20-m and S30-m performance accounted for 62 - 83% of the variation in RSTT scores whilst YYIR1 performance only accounted for 33.6%. The results of this study indicate that fast linear speed can positively impact on RSTT performance whilst reduced aerobic endurance capabilities may negatively

influence RSTT performance in female international footballers.

Keywords Sprinting, Endurance, Fatigue, Female, Football

1. Introduction

Elite female international football is a dynamic intermittent field sport that physiologically stresses the metabolic and neuromuscular systems [1,2]. Due to the random nature of football match play numerous contextual factors will influence the physical demands withstood by players such as playing position, formation, tactics, time in possession, team ranking and score line [3-5]. Players transition from long periods of aerobic activity to short bouts of high intensity anaerobic activities such as high speed running, sprinting and repeated high speed and sprinting actions [6 - 8].

During match play total distances covered fall within the range of 9 - 12km with the majority of distance covered walking or jogging with high speed running (> 18 km-h) been shown to account for 1.53 - 1.68 km of that total distance [7,5,9,10]. Total match play sprint distance reported within the literature differs due to the variation of

the sprint speed threshold implemented (19.1 km·h versus 20 km·h versus 25.1 km·h) [6,11,12]. Though players have been shown to cover mean distances in the range of .16 - .46 km sprinting during games and complete between 180 and 240 accelerations during a senior international match [5,9,10,11,12,13]. Repeated high speed actions consisting of two or more sprints with less than 20 seconds recovery between efforts occur approximately 31 – 33 times during international match play [6,8]. Although, it is not uncommon for players to perform up to 6 repeated high speed bouts with less than 20 second recovery between each bout [6,8,11]. However, the most frequent mean recovery time duration between repeated high speed running bouts in female international matches has been demonstrated to be 10 seconds or less [6]. Such repeated high speed and sprint efforts with minimal recovery time can result in a deterioration of high speed running, sprint and RSA performance, throughout international match-play [5,8,9,14].

RSA has been defined within the literature as short sprints typically less than ten seconds in duration with recovery periods sixty seconds or less [15]. Assessment of RSA identifies a player's capacity to maintain maximal effort and recovery during multiple successive high speed or sprint efforts a key attribute for athletes in field based team sports such as football [16]. Numerous assessment methods have been utilised to measure RSA performance in various populations of female football players such as 5 x 10-m Ajax sprint test, 7 x 30-m sprints with 30 seconds recovery, 10 x 30-m with 30 seconds recovery and 6 x 15 second cycles of 20-m maximal sprinting followed by a 10-m deceleration and a 10-m active recovery jog (Figure 1) making direct comparisons between studies challenging [17 – 21].

RSA performance is highly influenced by the testing protocol utilised (i.e. sprint duration, distance and number of repetitions as well as type of and duration of recovery) therefore any RSA assessment protocol should be reflective of the movement demands of the sport [16]. In addition, it must be noted that variables sprint duration, distance, number of repetitions and duration of recovery during match play will differ between playing positions [6,11]. Spencer et al [17] stated that mean sprint times and distances covered in field based team sports to be 2 – 3 seconds in duration and between 10 – 20m., findings supported by Gabbett et al [22] demonstrating mean sprint times of (2.1 ± 0.7 seconds). More recently Nakamura et al [11] highlighted similar results reporting mean sprint times of (2.5 ± 0.5 seconds) and mean sprint distances of (15.7 ± 2.6 m) in elite female footballers. Furthermore, the recovery period between 2 repeat high speed and sprint bouts the most frequent in female international football has been shown to be (9.42 ± 2.68 and 10.22 ± 4.42 seconds) respectively [6,8]. In addition, RSA assessment incorporating active recovery opposed to passive recovery may potentially reduce muscle acidosis and negate a

decline in RSA performances [17]. Considering 85% of the total distance covered during elite female match play is at walking and jogging speeds and approximately 95% of the activity between repeat high speed or sprint bouts is active in nature RSA assessment should include active recovery between each repeat sprint [9,22].

Similar to Lockie et al [23] this study will implement the RSA assessment protocol developed by Gabbett [21] for elite female footballers (see figure 1) as based on the presented literature the protocol appears to specifically address the RSA demands of elite female football match play. Gabbett [21] previously stated that RSA tests should be performed in conjunction with a maximal aerobic endurance and linear speed assessments. As a highly developed aerobic endurance capacity may benefit recovery between repeated high speed or sprint bouts during match play [19]. Therefore, the purpose of this study was to undertake the hypothesis stated by Gabbett [21] and examine the relationship of aerobic endurance (YYIR1) and linear speed (S10-m, S20-m, S-30m and RST1) on RSA performance in female international footballers

2. Materials & Methods

2.1. Experimental Approach to the Problem

Physical assessments were conducted in the following order 10-m, 20-m, 30-m linear sprints, RSA and Yo-Yo Intermittent Recovery Test, level 1 (YYIR1). Assessments took place in two separate testing sessions on the first day of each squads relevant training camp during 2019. All tests were performed in the afternoon between the hours of (12:00 and 16:00). Subjects were provided at least a 15-minute recovery period between tests to assuage any effects of fatigue. Every test was performed indoors on a rigid surface with all subjects wearing running shoes. Prior to the initiation of the testing session, participants underwent a structured 10 minute warm up protocol consisting of jogging, running, lower limb mobility and dynamic stretching movements. On completion of the warm up a 5-minute recovery period was employed to assuage any effects of fatigue. Any participants diagnosed with a lower limb injury were excluded from testing.

2.2. Participants

Twenty-five female elite level football players selected to represent the Ireland u19 or senior international team participated in the study (mean \pm SD; age 19.1 ± 3.4 years; height 167 ± 6 cm; mass 62.5 ± 7.4 kg). Ethical approval was obtained by the college Research Ethics Committee. The participants were informed of the risks of the study in person and writing. An informed consent document was signed before the beginning of data collection and participants were free to withdraw from the study at any

(10-m,20-m,30-m linear sprints, initial 20-m repeat sprint trial and yo-yo intermittent recovery test). The Durban Watson test was applied in the residual of regression analysis. Furthermore, the analysis of variance (ANOVA) test allowed to determine if the linear regression tests were significant.

3. Results

Descriptive statistics for all performance test are presented in (Table 1). Pearson product correlation (r) analysis identified a large significant relationship existed between YYIR1 and RSTT ($r = -0.58$, $P = 0.002$) whilst significant medium to large negative relationships were present with S10-m ($r = -0.42$, $P = 0.038$), S20-m ($r = -0.52$, $P = 0.008$), S30-m ($r = -0.50$, $P = 0.011$), RST1 ($r = -0.58$, $P = 0.03$) and YYIR1. Very large significant relationships were established between S10-m ($r = 0.78$, $P = 0.0001$) and S20-m ($r = 0.89$, $P = 0.0001$) with RSTT. In addition, an almost perfect relationship was revealed between S30-m ($r = 0.92$, $P = 0.0001$) and RST1 ($r = 0.92$, $P = 0.0001$) with RSTT. In terms of rate of fatigue there was no significant relationship established between either FI or Sdec and RSTT. (table 2).

Table 1. Descriptive statistics of Repeat sprint ability, Linear speed and Aerobic endurance tests (mean \pm SD)

Test	N	Mean + SD	CI 95%	
			Lower	Upper
RSTT (seconds)	25	21.42 \pm .97	21.02	21.82
RST1 (seconds)	25	3.43 \pm .16	3.37	3.5
FI (%)	25	8.34 \pm 2.55	7.28	9.39
Sdec (%)	25	4.38 \pm .26	3.84	4.93
YYIR1 (m)	25	1080 \pm 375	925	1235
10-m (seconds)	25	1.92 \pm .09	1.88	1.96
20-m (seconds)	25	3.31 \pm .15	3.25	3.37
30-m (seconds)	25	4.62 \pm .21	4.53	4.71

Analysis of YYIR1 results indicated the high performing group to significantly cover more distance during the YYIR1 (1345 \pm 260 m vs 741 \pm 162 m, $P = 0.0001$, $ES = 2.27$), performed faster RSTT (21.07 \pm 0.80 vs 21.87 \pm 1.0 seconds, $P = 0.036$, $ES = 0.88$) and RST1 times (3.37 \pm 0.13 vs 3.51 \pm .17 seconds, $P = 0.029$, $ES = 0.94$). No statistically significant differences were reported between the high and low groups for S10-m, S20-m and S30-m assessment though moderate effect sizes ($ES = 0.56$, 0.63 , and 0.58) in favor of the high YYIR1 group were present for all distances. In terms of levels of FI (7.92 \pm 2.7 vs 8.86 \pm 2.38 %, $ES = 0.37$) and Sdec% (4.48 \pm 1.56 vs 4.26 \pm 1%, $ES = 0.16$) sustained during RSA test small to trivial differences existed between the high and low YYIR1

groups. Linear regression analysis and predicative equations are presented in (table 2).

Table 2. Linear regression data and predicative equations for RSTT versus all independent variables

Independent variables	R2	Predictive Equation
YYIR1	33.60%	RSTT= 23.03 + -.001 "YYIR1 distance"
S10-m	62.10%	RSTT = 6.422 + 7.804 "S10m"
S20-m	79.90%	RSTT = 2.203 + 5.81 " S20 m"
S30-m	83.80%	RSTT = 1.997 + 4.203 "30m"
RST1	85.40%	RSTT = 2.224 + 5.590 "RST1"

4. Discussion

This study is the first of its kind to investigate the relationship between aerobic endurance (YYIR1) and linear speed (S10-m, S20-m and S30-m) on RSA (RSTT and RST1) performance in female international footballers. The RSTT for the female international football players in this study (21.42 \pm .97 seconds) was slower than the national level players (20.09 \pm .5 seconds) evaluated by Gabbett [21] but quicker than state (23.3 \pm .04 seconds) and collegiate level players (22.09 \pm .99 seconds) [21,23]. The fatigue index also termed performance decrement (PD) for the players in this study (8.34 \pm 2.5 %) was greater in comparison to that of the national (6.2 \pm 1.6 %) and state level (6.8 \pm 2.7 %) players examined by Gabbett [21] but less than the collegiate players (8.37 \pm 5.51 %) investigated by Lockie et al [23]. In addition, this study was the first to describe the Sdec (4.38 \pm .26 %) in female international football players using this RSA test protocol. The Sdec method has been shown to be the most valid and reliable method of measuring fatigue in RSA assessment as it accounts for all sprints performed opposed to FI or PD which only considers the first and last sprint a scenario which may be considerably influenced by one good or bad repetition during a RSA assessment [29]. However, in this cohort Sdec showed no significant relationship with RSTT ($r = 0.38$, $P = .19$). Future studies should further investigate if Sdec is a more reliable measure of fatigue during RSA assessment of elite female football players as both FI or PD have previously been shown not to be in national, state and collegiate level football players as well as the cohort in this current investigation ($r = 0.29$, $P = .17$) [21,23].

Aerobic endurance would appear to play a significant role in RSA performance as a large negative correlation highlighted players that covered greater distances in the YYIR1 achieved faster RSTT times (Fig 2). Although the test protocols differed the results of this study would concur with Shalfawi et al [19] findings which reported similar large negative correlations ($r = -0.59$, $P = <0.01$) between RSTT (10 x 30-m with 30 seconds recovery between reps) and aerobic fitness (multi stage fitness test)

in elite female club level footballers. In contrast Lockie et al [23] using the same test protocols as this study reported no significant relationship between RSTT and YYIR1 performance ($r = -0.03$, $P = 0.91$). Furthermore, the presence of significant medium to large negative relationships between YYIR1 and S10-m, S20-m, S30-m and RST1 replicates a trend previously established in elite female club level players [19]. Similar to Sanders et al [20] findings on female collegiate level football players 30-m sprint performance it would appear that the players in this study who possessed higher aerobic endurance capabilities on average were faster over S10-m, S20-m and S30-m distances.

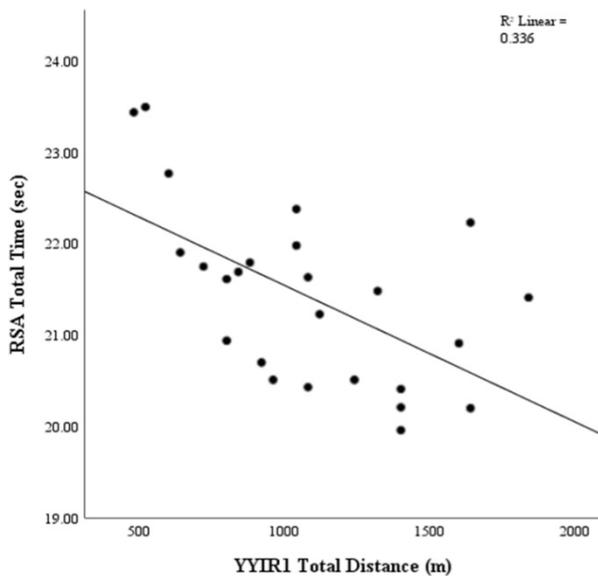


Figure 2. Scatterplot and line of best fit for the relationship between YYIR1 and RSTT

A growing body of research emanating from numerous populations of female football players indicates a strong relationship between linear speed performance over various distances and RSTT [19,20,23]. Contrary to Gabbett [21] ($r = 0.02$, $P < 0.05$) this study found a very large significant relationship between S10-m and RSTT performance which was greater than the significantly large relationship previously reported by Lockie et al [23] in collegiate level players ($r = 0.50$, $P = 0.03$). Over the longer distances of 0-20-m and 0-30-m this current study as well as Shalfawi et al [19] ($r = 0.73$, $P < 0.01$) both highlighted very large significant relationship between S20-m performance and RSTT. While Lockie et al [23] displayed a similar trend between 30-m and RSTT performance ($r = 0.71$, $P < 0.01$) which was further supported by the research findings of this study which highlighted an almost perfect relationship. Furthermore, akin to Gabbett ($r = 0.96$, $P < 0.001$) an almost perfect significant relationship ($r = 0.92$, $P < 0.01$) was present between RST1 and RSTT performance in this cohort of 1 players [21]. Linear regression analysis revealed RST1 was

the most strongly correlated with RSTT accounting for 85% variance in comparison to S10-m, S20-m and S30-m which accounted for 62.1%, 79.9% and 83.8% variance in RSTT performances. YYIR1 was deemed to have a more moderate influence on RSTT in comparison to all linear speed assessments with the aerobic endurance assessment being responsible for 33.6% of the variance in RSTT.

5. Conclusions

There are a number of limitations to this investigation that should be addressed. The sample size of this study is a combination of two international age groups (U19 and senior) therefore the generalisation of these results must be interpreted with caution. Future RSA research should specifically examine all competitive international age categories (i.e., U17, U19 and senior). In addition, no physiological markers such as heart-rate [21] were assessed during the RSA test which may have been of benefit. However, significant relationships were observed between aerobic endurance and linear speed with RSA performance. The results from this study indicate a player's RSA will be influenced by the inter-play of both their aerobic endurance and linear speed capabilities opposed to either one independently. Therefore, it may be suggested that separate training strategies for aerobic endurance and linear speed are required to improve a player's RSA.

6. Practical Application

In order to fully optimise RSA performance of elite female footballer's coaches, strength and conditioning coaches and sports scientist alike should implement a concurrent training strategy. For instance, small sided games are common practice in the development of female football player's aerobic capacity though they have been shown not to meet the high speed, very high speed and sprinting demands of international match play [30]. One may suggest that aerobic endurance development can be targeted via various sized small sided games whilst linear speed development can be addressed through sprint training and power development. Though it must be noted that any training program designed to optimise RSA is structured so both aerobic and linear speed development are emphasised in conjunction with the team's competition demands and the individual capabilities of the player.

Acknowledgements

We would like to thank the players and staff at the Football Association of Ireland for their hard work and cooperation throughout the study.

Disclosure Statement

No potential conflict of interest was reported by the authors

Funding

Funding for this research was provided by the Institute of Technology Carlow and the Football Association of Ireland.

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