ORIGINAL ARTICLE

An analysis of the relationship between critical velocity and anaerobic speed reserve with match running profile in football

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim: The aim of this study was to analyse the relationship between critical velocity (CV) and anaerobic speed reserve (ASR) with match running profile in football.

Material and Methods: The research group consisted of fifteen young male football players (n=15, age=16.60±0.51 years, height=177.40±5.25 cm, weight=67.20±5.52 kg, body mass index=21.32±0.96 kg/m^2). Yo-Yo intermittent recovery level 1 test (Yo-Yo IRT) was performed to determine maximal aerobic speed (MAS). Maximal sprint speed (MSS) was determined by 30-meter sprint test. CV and ADC parameters were obtained by linear regression model (Lin-TD: linear total distance model) between the covered distance and running duration in 800-meter and 2400-meter running tests. A 90-minutes football match was played to determine the subjects' match running profile (covered distance in every running category), which was examined by means of a global positioning system (GPS) device in five running categories (walking: 0-6.9 km/h, low intensity running: 7-12.9 km/h, middle intensity running: 13-17.9 km/h, high intensity running: 18-20.9 km/h, sprint: >21 km/h). Correlation analysis and multiple linear regression analysis was employed to analyse the collected data.

Results: It was found that CV was significantly and positively correlated with total running distance as well as low and middle intensity running ($p<0.05$). A significant and negative correlation was found between ASR and all match running profiles ($p<0.05$). Both CV and ASR were significant predictors of high intensity running, maximum running speed and total running distance during match ($p<0.05$). However, while CV was a significant predictor of sprint running, ASR significantly predicted walking ($p<0.05$).

Conclusions: Consequently, it may be concluded that in football, aerobic fitness is positively correlated to CV and negatively to ASR.

Keywords: anaerobic speed reserve, critical velocity, football running profile.

Introduction

Football is a sports branch that involves a wide range of different physical activities such as jumping, tackles, walking, change of direction and backward running. The activities required during a football match are predominantly low intensity activities [1]. The repeated and intermittent exercises during a football match necessitate aerobic fitness and high recovery capacity [2]. Football players are required to have high aerobic endurance for successful match performance. The players' energy requirement during match is met by their aerobic energy metabolism to a substantial extent (90%) [3]. Also, high aerobic fitness provides faster recovery after anaerobic exercises through the effective use of aerobic energy pathways [4]. Football players cover considerable distance with a range of physical activities during match. It was indicated that players playing in European elite football teams covered 10.7-12 km distance during match [5], which means that football matches involve activities that require aerobic fitness due to match length [6]. Yet, high intensity and sprint running are at least as important as they determine match performance. It was reported that football matches involved high intensity activities inducing lactate accumulation [6]. The removal of lactate from blood is important for endurance, while aerobic fitness supports the players in terms of high repeated sprint performance. Therefore, the determination of match running profile may be helpful in determining appropriate physical exercises for shorter recovery periods through increased lactate tolerance.

One parameter of aerobic endurance is critical velocity (CV). CV refers to the highest exercise intensity that can theoretically be sustained without fatigue in a prolonged exercise [7, 8, 9]. Maximum oxygen uptake (VO_{2max}) is reached gradually once CV is surpassed, and CV represents the lower exercise limit that stimulates VO_{2max} [10, 11]. CV is defined as an indicator of aerobic fitness level. CV is determined by linear regression analysis between the covered distance and running duration. According to the linear regression model, the slope of regression line is defined as CV, and the interception on y-axis of the line represents the anaerobic distance capacity

doi:10.15561/26649837.2022.0601

(ADC) [12]. ADC is the limited anaerobic energy source of the muscles, and it is indicated that any given distance is covered according to this reserve [13]. CV is a simple indicator of aerobic fitness level in athletes. It was indicated that marathon running time was related to the CV parameter [13]. Marathon running is an exercise that requires high aerobic endurance, which is confirmative of the relationship between CV and aerobic fitness. Considering that football is a sports branch requiring high aerobic endurance, CV may serve as a useful performance parameter, and hence be a helpful tool to determine aerobic exercise intensity in football.

One of the anaerobic parameters is anaerobic speed reserve (ASR). The lowest speed at which maximum oxygen consumption occurs is known as maximum aerobic speed (MAS) [14, 15, 16], and ASR is the difference between MAS and maximal sprint speed (MSS) [17, 18]. It was indicated that ASR could be used to predict performance in high intensity exercises [17, 18]. ASR may be used as an alternative performance evaluation parameter to anaerobic power tests [19]. It was determined that the lower the ASR value, the better the repeated sprint performance [20]. This finding showed that the aerobic energy metabolism supported resistance against fatigue in athletes with lower ASR. Football players must show high tolerance to fatigue during match. Therefore, aerobic energy metabolism is a key factor for football players. Determining the relationship between ASR and match running profile (walking, low and high intensity running, and sprint) can therefore be a useful tool for coaches and sports scientists. CV, ADC and ASR parameters can be helpful in measuring and monitoring the aerobic and anaerobic fitness levels of players, and hence, be used as a baseline when planning the most adequate exercises with a view to achieve improved aerobic and anaerobic fitness levels in football players. The aim of this study was to examine the effects of CV, ADC and ASR parameters on match running profile.

Material and Methods

Participants

The research group consisted of fifteen young male football players (n=15, age=16,60±0,51 years, height=177,40±5,25 cm, weight=67,20±5,52 kg, body mass index=21,32±0,96 kg/m^2), who were attending regular training sessions in the young team of a professional football team competing in the Turkish Super League. The research procedure was explained to subjects in detail. The subjects filled informed consent forms and participated in the study voluntarily. The research was performed in accordance with the principles of the Helsinki Declaration.

Research Design

Data Collection

All tests were performed two days apart. The tests were conducted in the same hour of the day to prevent the effects of biological rhythm on physical performance. The effect of environmental conditions and pitch ground was minimized by performing all of the tests on natural grass football pitch and in sunny weather conditions. A warm-up period of 10 minutes was applied before all tests. The procedure applied during tests is explained below.

Maximal Aerobic Speed Test

The players' maximal aerobic speed values were determined by Yo-Yo intermittent recovery level 1 test (Yo-Yo IRT), which was conducted on natural grass football pitch. The 25-meter test track consisted of a 5-meter recovery zone and a 20-meter running zone (Figure 1).

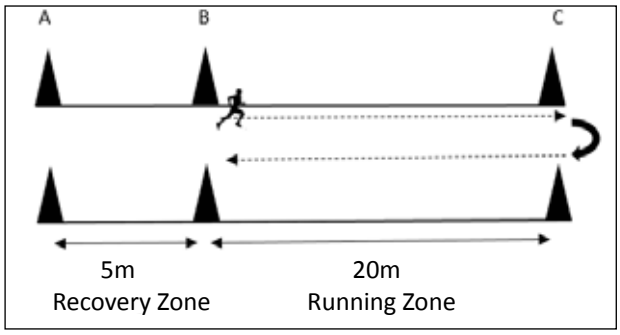

Figure 1. Yo-Yo Intermittent Recovery Level 1 Test Track.

The players began running in the 20-meter zone in time to a beep sound emitted from a loudspeaker connected to a computer. Players tried to reach the start and end of the 20-meter zone by the time the next beep was emitted each time. Subsequent to every out and back shuttle (40-meters) in the 20-meter running zone, the players performed 10-meter low intensity running (2x5-meter running with turning) in the 5-meter recovery zone until the next beep. Yo-Yo IRT was commenced at 10 km/h speed. The test was started, and players covered 160 meters (4x40 meters) at 10-13 km/h and then 280 meters (7x40 meters) at 13.5-14 km/h speed. After that, running speed was gradually increased by 0.5 km/h every 320 meters (8x40 meters) until end of the test. The test was terminated when a player failed to complete a successful shuttle in the allocated time twice consecutively or ended the test voluntarily. The final speed of test was recorded as maximal aerobic speed (MAS). Also, the distance covered in the test was recorded to test form. The maximum oxygen uptake (VO_{2max}) values in the test were determined by the formula below [21]:

$$VO_{2max}\ (ml/kg/min) = \text{Covered distance in Yo-Yo IRT (m)} \times 0.0084 + 36.4$$

Sprint Tests

30-meter sprint test was performed to determine maximal sprint speed (MSS). A 30-meter sprint track was established on natural grass football

pitch. Sprint time was measured by wireless photocell system (Witty, Microgate, Bolzano, Italy) that comprised three gates, which were put up at the start, 10-meter, and finish points of the test, respectively (Figure 2).

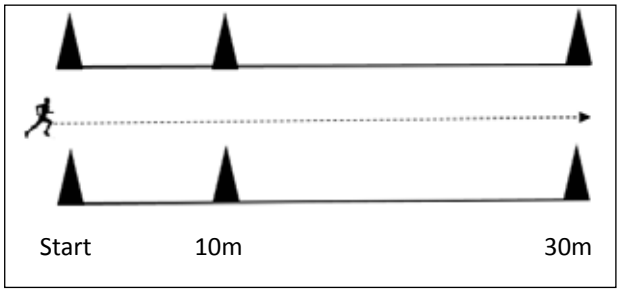

Figure 2. Sprint Test Track

After warm-up exercises, the players performed a one-time sprint run to get used to the test. The photocell system automatically started when the players passed the start gate of the device. The players did their sprint run with maximal speed, accompanied by verbal encouragement. The photocell device automatically stopped when player passed the fourth gate. The 0-10- (sprint time between start and 10-meter), 10-30- (interval sprint time between 10- and 30-meter) and 0–30-meter sprint time (sprint time between start and 30-meter) of players were recorded in seconds by the device software. The test was performed twice, and the best sprint time was accepted as test score. The speed values of 0-10-, 10-30- and 0–30-meter sprint was calculated in km/h using the speed=distance/time formula on Excel (Microsoft Excel, Microsoft Office 365, Redmond, WA, USA). The speed value of the best 10-30-meter sprint running was determined as maximal sprint speed (MSS) [19].

Anaerobic Speed Reserve

Anaerobic speed reserve (ASR) is defined as the indicator of a-lactic anaerobic sprint performance [19]. ASR was determined by the formula below [18]:

Anaerobic speed reserve (km/h) = Maximal sprint speed (km/h) – Maximal aerobic speed (km/h)

Critical Velocity Tests

Critical velocity (CV) and anaerobic distance capacity (ADC) were determined by 800- and 2400-meter maximal running tests [22]. The players performed the 800 and 2400-meter running test on natural grass football pitch. The 800 and 2400-meter running tracks were measured and marked with training cones. The tests were performed two days apart in the same hour of the day and in sunny weather conditions. After warm-up exercises, players performed the running tests with maximal effort. Verbal encouragement was given to players by trainers. 800- and 2400-meter running times were measured by a professional hand stopwatch in seconds (Casio HS-80TW-1DF, Casio Computer Ltd, Tokyo, Japan). The running times were recorded to test form. CV and ADC parameters were determined using 800 and 2400-meter running distance and running times by Linear Total Distance Model (Lin-TD), which employed the linear regression formula shown below and consisted of a linear regression analysis between the distances covered and running times on the 800- and 2400-meter tracks [8, 12, 13, 23, 24, 25, 26, 27, 28, 29, 30]:

Running distance (D) = ADC + CV x Running time (t)

Match Running Profile

A football match was played on natural grass pitch with regular dimensions in 11v11 format. The running profile during match was determined by global positioning system (GPS) receivers transferring data at a frequency of 10 Hertz (GPSsport EVO, GPSsport, Canberra, Australia). GPS system software was installed on a notebook. The running profile during match was divided into five categories as shown in Table 1 [31]. GPS receivers determined the mean, maximum, and total running distance parameters. The match running profile (covered distance in every running category) was automatically recorded by software of the GPS system. The players wore GPS vests, with GPS receivers put into the pockets of the vests. The young football players performed a warm-up exercise period before match. The GPS receivers commenced recording the running profile when the match started. The football match lasted for two equal halves according to official rules. The running data of players who played the entire match (90 minutes) were included in analysis.

Table 1. Match Running Profile Parameters [31]

Match Running Profile Categories	Running Speed Intervals (km/h)
Walking	0-6.9 km/h
Low intensity running	7-12.9 km/h
Middle intensity running	13-17.9 km/h
High intensity running	18-20.9 km/h
Sprint running	>21 km/h

Statistical Analysis

The SPSS statistic package program was used for all analysis (SPSS Version 20.0, IBM Corporation, Armonk, New York, USA). All data was presented in descriptive values (mean, standard deviation, minimum, maximum values). Suitability to normal data distribution was examined by a Shapiro-Wilks test. The relationship between match running profile with other test parameters was determined by Pearson and Spearman correlation coefficients. Multiple linear regression analysis was used to determine the effects of test parameters on match running profile parameters. The linear regression models consisted of one dependent (match running profile parameters) and three independent variables (CV, ADC and ASR). The collinearity between

independent variables was examined by VIF (variance inflation factor) coefficients and tolerance values. The significance value in all analysis was established as $p<0.05$.

Results

According to mean values of the tests (Table 2), it was found that the longest distance covered by young football players during match was with middle intensity running (13-17,9 km/h). Also, the players spent the most time at 188-220 beat/min heart rate interval during match. The mean maximum oxygen uptake values of players were found as 53,39 ml/kg/min during Yo-Yo IRT.

The correlation between match running profile

Table 2. Physical Characteristics and Test Parameters of Young Football Players (n=15)

Parameters		Mean ($\bar{x}$)	Standard Deviation (SD)	Min.	Max.
Physical Characteristics	Age (years)	16.60	0.51	16.00	17.00
	Height (cm)	177.40	5.25	166.00	185.00
	Weight (kg)	67.20	5.52	58.00	80.00
	Body mass index (kg/m^2)	21.32	0.96	19.69	23.37
Match Running Profile	Walking (0-6.9 km/h)	489.33	93.51	325.00	645.00
	Low intensity running (7-12.9 km/h)	635.27	109.22	489.00	878.00
	Middle intensity running (13-17.9 km/h)	1081.00	259.54	713.00	1482.00
	High intensity running (18-20.9 km/h)	77.93	120.06	0.00	400.00
	Sprint running (>21 km/h)	2.47	8.04	0.00	31.00
	Mean running speed (km/h)	8.34	0.52	7.20	9.10
	Maximum running speed (km/h)	19.50	1.28	16.90	22.30
	Total running distance (m)	2288.40	482.40	1642.00	3416.00
Match Heart Rate Profile	Time spent between 0-120 beat/min (sec)	36.60	103.47	0.00	394.00
	Time spent between 121-144 beat/min (sec)	23.20	16.72	0.00	53.00
	Time spent between 145-164 beat/min (sec)	65.73	49.11	10.00	190.00
	Time spent between 165-176 beat/min (sec)	149.87	139.40	28.00	561.00
	Time spent between 177-188 beat/min (sec)	327.93	162.71	85.00	637.00
	Time spent between 188-220 beat/min (sec)	381.93	264.71	0.00	828.00
	Mean heart rate (beat/min)	181.80	6.53	172.00	194.00
	Maximum heart rate (beat/min)	196.73	6.54	184.00	210.00
	% Heart rate (% of maximum heart rate)	90.73	3.20	86.00	97.00
Test Parameters	Critical velocity (km/h)	14.43	0.93	13.58	17.04
	Anaerobic distance capacity (m)	115.52	37.94	45.78	185.20
	Anaerobic speed reserve (km/h)	11.32	1.27	8.67	13.27
	Yo-Yo IRT VO_{2max} (ml/kg/min)	53.39	3.63	48.50	62.27
	Yo-Yo IRT final speed (km/h)	16.73	0.70	16.00	18.50
	Yo-Yo IRT distance (m)	2022.67	431.73	1440.00	3080.00
	800 meter running time (sec)	172.40	10.70	151.00	194.00
	2400 meter running time (sec)	572.87	28.02	489.00	604.00
	10-meter sprint time (sec)	1.77	0.04	1.69	1.84
	10-meter sprint speed (km/h)	20.33	0.49	19.57	21.30
	30-meter sprint time (sec)	4.34	0.10	4.20	4.47
	30-meter sprint speed (km/h)	24.89	0.58	24.16	25.71
	20-meter (between10-30-meter) sprint time (sec)	2.57	0.07	2.46	2.70
	20-meter (between10-30-meter) sprint speed (km/h) (MSS)	28.05	0.82	26.67	29.27

Min.: Minimum, Max.: Maximum, MSS: Maximal sprint speed

parameters and test results is presented in Table 3. CV was found to be significantly correlated with total running distance, low and middle intensity running ($p<0.05$). There was no significant correlation between match running profile parameters and ADC ($p>0.05$). However, ASR was significantly correlated with all match running profile parameters except for mean running speed ($p<0.05$). In terms of other test parameters, it was found that Yo-Yo IRT results were correlated with match running profile parameters except for mean running speed ($p<0.01$). 800-meter running time was significantly correlated with maximum running speed, high intensity and sprint running ($p<0.05$). Furthermore, it was found that 2400-meter running time was significantly correlated with low and middle intensity running, maximum running speed, and total running distance ($p<0.05$).

The test results' effect on match running profile parameters is presented in Table 4. According to the variance explanation proportion of multiple regression models, CV, ADC, and ASR explained the variance on maximum running speed at the highest rate (R^2=0,829, $p<0.05$). It was determined that ADC was the most effective parameter on maximum running speed according to standardized Beta coefficients of the regression model (β=0,609, $p<0.05$). Also, all-independent variables (CV, ADC and ASR) had significant effect on high intensity running (β=0,743, 0,575, -0,387, $p<0.05$, respectively). All parameters explained variance on high intensity running with 74,6% (R^2 = 0,746, $p<0.05$). However, it was found that CV was the most effective parameter on high intensity running (β=0,743, $p<0.05$) and sprint running (β=0,824, $p<0.05$). Along with that, CV and ASR parameters explained variance on total

Table 3. Correlation Coefficients between Match Running Profile and Test Parameters (n=15)

Test Parameters	Match Running Profile							
	Walking (0-6.9 km/h)	**Low intensity running (7-12.9 km/h)**	**Middle intensity running (13-17.9 km/h)**	**High intensity running (18-20.9 km/h)**	**Sprint running (>21 km/h)**	**Mean running speed (km/h)**	**Maximum running speed (km/h)**	**Total running distance (m)**
CV (km/h)	0.225	0.572*	0.580*	0.063	0.380	0.259	0.394	0.634*
ADC (m)	0.234	-0.209	-0.114	0.132	-0.161	-0.194	0.289	-0.032
ASR (km/h)	-0.644**	-0.632*	-0.583*	-0.669**	-0.643**	-0.038	-0.773**	-0.758**
Yo-Yo IRT VO_{2max} (ml/kg/min)	0.828**	0.733**	0.791**	0.804**	0.721**	0.012	0.842**	0.964**
Yo-Yo IRT final speed (km/h)	0.809**	0.744**	0.715**	0.751**	0.589*	-0.027	0.850**	0.931**
Yo-Yo IRT distance (m)	0.828**	0.734**	0.791**	0.804**	0.721**	0.012	0.842**	0.964**
800 meter running time (sec)	-0.351	-0.288	-0.247	-0.689**	-0.598*	0.012	-0.622*	-0.448
2400 meter running time (sec)	-0.296	-0.577*	-0.580*	-0.329	-0.465	-0.223	-0.541*	-0.688**
10-meter sprint time (sec)	-0.163	0.063	-0.028	0.276	0.298	0.180	0.019	0.041
10-meter sprint speed (km/h)	0.166	-0.063	0.036	-0.277	-0.296	-0.175	-0.020	-0.036
30-meter sprint time (sec)	0.156	0.274	0.201	0.353	0.389	0.134	0.359	0.294
30-meter sprint speed (km/h)	-0.154	-0.277	-0.196	-0.347	-0.385	-0.131	-0.353	-0.290
20-meter sprint time (sec)	0.301	0.333	0.286	0.321	0.357	0.079	0.472	0.373
20-meter sprint speed (km/h)	-0.305	-0.342	-0.290	-0.316	-0.354	-0.082	-0.470	-0.377

*p<0.05, **p<0.01, CV: critical velocity, ADC: anaerobic distance capacity, ASR: anaerobic speed reserve

Table 4. Multiple Linear Regression Analysis Results Regarding the Effects of Critical Velocity, Anaerobic Distance Capacity and Anaerobic Speed Reserve on Match Running Profile

Dependent Variable	Predictor Variables	B	β	p	R^2
Walking (0-6.9 km/h)	constant	510.976		0.420	0.500
	CV	23.275	0.232	0.455	
	ADC	0.927	0.376	0.201	
	ASR	-41.050	-0.558	0.041†	
	*F=3.667. **p<0.05				
	Model: walking = 510.976 + 23.275 x CV + 0.927 x ADC - 41.050 x ASR				
Low intensity running (7-12.9 km/h)	**Predictor Variables**	**B**	**β**	**p**	**R^2**
	constant	384.474		0.590	0.527
	CV	48.360	0.413	0.185	
	ADC	0.112	0.039	0.887	
	ASR	-40.653	-0.473	0.069	
	*F=4.088. **p<0.05				
	Model: low intensity running = 384.474 + 48.360 x CV + 0.112 x ADC - 40.653 x ASR				
Middle intensity running (13-17.9 km/h)	**Predictor Variables**	**B**	**β**	**p**	**R^2**
	constant	-581.931		0.732	0.520
	CV	160.603	0.577	0.076	
	ADC	1.574	0.230	0.414	
	ASR	-73.949	-0.362	0.155	
	*F= 3.967. **p<0.05				
	Model: middle intensity running = -581.931 + 160.603 x CV + 1.574 x ADC – 73.949 x ASR				
High intensity running (18-20.9 km/h)	**Predictor Variables**	**B**	**β**	**p**	**R^2**
	constant	-1099.778		0.074	0.746
	CV	95.727	0.743	0.005†	
	ADC	1.818	0.575	0.014†	
	ASR	-36.579	-0.387	0.046†	
	*F=10.771. **p<0.05				
	Model: high intensity running = -1099.778 + 95.727 x CV + 1.818 x ADC – 36.579 x ASR				
Sprint running (>21 km/h)	**Predictor Variables**	**B**	**β**	**p**	**R^2**
	constant	-84.808		0.033†	0.781
	CV	7.113	0.824	0.002†	
	ADC	0.070	0.329	0.100	
	ASR	-2.072	-0.328	0.066	
	*F=13.046. **p<0.05				
	Model: sprint running = -84.808 + 7.113 x CV + 0.070 x ADC – 2.072 x ASR				
Mean running speed (km/h)	**Predictor Variables**	**B**	**β**	**p**	**R^2**
	constant	6.049		0.215	0.072
	CV	0.143	0.258	0.541	
	ADC	-0.001	-0.042	0.913	
	ASR	0.025	0.062	0.853	
	*F=0.286. **p>0.05				
	Model: mean running speed = 6.049 + 0.143 x CV – 0.001 x ADC + 0.025 x ASR				

Table 4. (continued).

Dependent Variable	Predictor Variables	B	β	p	R^2
	Predictor Variables	**B**	**β**	**p**	**R^2**
Maximum running speed (km/h)	constant	13.071		0.022†	0.829
	CV	0.734	0.533	0.011†	
	ADC	0.021	0.609	0.003†	
	ASR	-0.578	-0.573	0.002†	
	*F=17.838. **p<0.05				
	Model: maximum running speed = 13.071 + 0.734 x CV + 0.021 x ADC – 0.578 x ASR				
Total running distance (m)	**Predictor Variables**	**B**	**β**	**p**	**R^2**
	constant	-863.987		0.682	0.787
	CV	334.617	0.646	0.007	
	ADC	4.514	0.355	0.075	
	ASR	-194.254	-0.512	0.008	
	*F=13.557 . **p<0.05				
	Model: total running distance = -863.987 + 334.617 x CV + 4.514 x ADC – 194.254 x ASR				

† - p<0,05, * Coefficient of regression model, ** significance value of regression model, CV: critical velocity, ADC: anaerobic distance capacity, ASR: anaerobic speed reference.

running distance with 78,7% (R^2=0,787, p<0.05) in the regression model. It was seen that CV was the most effective parameter on total running distance (β=0,646, p<0.05). The independent variables (CV, ADC, and ASR) had no significant effect on mean running speed, low and middle intensity running parameters although the regression models were statistically significant (p>0.05).

Discussion

The research results showed that CV was significantly correlated with total running distance, low and middle intensity running in football match (Table 3). In contrast, ADC was not significantly correlated with match running profile parameters (Table 3). ASR was negatively correlated with all match running parameters except for mean running speed (Table 3). Multiple regression analysis demonstrated that the CV, ADC, and ASR parameters were significant predictors of high intensity running and maximum running speed parameters in football match (Table 4). Furthermore, CV was predictive of sprint running and total running distance while ASR had significant effect on walking and total running distance (Table 4).

In a study by Aquino et al., a positive correlation was found between Yo-Yo IRT total distance and medium intensity running (8.1-13.0 km/h) in football match [32]. In our study, Yo-Yo IRT distance was found to be positively correlated with low intensity running (7-12.9 km/h). Moreover, our study confirmed a moderately positive relationship between CV and low and high intensity running. These findings support the results found by Aquino et al. [32]. Both researches were conducted on young football players. Hence, the similarity between the findings of the two researches may be attributable to similarity of the sample groups. Moreover, Yo-Yo IRT total distance was positively related to high intensity running (13-18 km/h). Likewise, total activities (sum of sprint (>18 km/h) and high intensity running) was positively related to total distance covered in football match [33]. High intensity and sprint running were found to be related to Yo-Yo IRT distance in our study. According to the findings of the present research, it was also found that CV was a predictor of high intensity running, sprint, and total distance in football match. CV is an aerobic fitness parameter, and this relationship is similar to the Yo-Yo IRT performance-match performance relationship. These findings show that football match performance is related to aerobic performance tests like Yo-Yo IRT.

It was found that the repeated anaerobic sprint test parameters (mean and total test time, mean and total sprint speed, minimum, mean and maximum power, fatigue index) of amateur football players were significantly correlated with ADC and 800-m running test (running time, mean and maximum running speed) parameters [34]. This showed that ADC was effective on repeated sprint performance. On the other hand, both the ADC parameter of the Lin-TD model and the CV parameter of the linear velocity model, which is the other linear regression model used for determination of CV and ADC, were found to be significantly correlated with Yo-Yo IRT VO_{2max} and distance values in young football players [35]. It may be said that Yo-Yo IRT test performance depends on aerobic endurance to a significant extent. Since aerobic fitness is a supporter of

anaerobic capacity, it can be stated that ADC may accompany the CV-Yo-Yo IRT relationship. A study by Ari demonstrated that the CV values of young football players were positively correlated with their medium intensity running numbers, the distance covered with medium intensity running (medium intensity running: 13-17.9 km/h) and total covered distance during football match [36]. The relationship found between CV and middle intensity running and total running distance supports the findings of the mentioned study. These findings indicated that CV was an indicator of aerobic performance in football.

Redkva et al. found that Yo-Yo IRT distance values were significantly correlated with the total covered distance, high intensity activity and sprint numbers during football match [37]. Our findings were similar to the results of that study. In our study, all match running parameters were found to be significantly correlated to the Yo-Yo IRT distance value except for mean running speed. All findings indicated that Yo-Yo IRT was a valid field test in football. Hence, running performance in football players may be tracked by their Yo-Yo IRT performance.

ASR was significantly correlated with the match running profile except for mean running speed in our study. In a study by Ortiz et al., it was shown that ASR was significantly correlated with the MAS and MSS values of football players [38]. Similar to ASR, Yo-Yo IRT parameters were found to be closely related to match running profile parameters in our study. It was observed that there was a parallelism between ASR and Yo-Yo IRT. The MAS parameter is usually determined by aerobic endurance tests such as Yo-Yo IRT. In our study, Yo-Yo IRT performance as an indicator of MAS was positively related to match running profile parameters while there was a negative correlation between ASR and match running profile. The negative correlation between match running profile parameters and ASR revealed that the aerobic effect on match performance was high. The difference in ASR is reportedly attributable to the difference in MAS values [39]. The ASR values of athletes may be different although their MAS values are same. This difference is due to the MSS value. The ASR value of athletes with higher MSS is higher than those with low MSS, although their MAS values are same. Therefore, athletes with higher MSS may perform exercises with a lower ASR percentage compared to athletes with lower MSS in the same exercise intensity [39]. Anaerobic activities such as sprint are frequently performed during the match. However, in football, the contribution of the aerobic system to performance is higher than the anaerobic metabolism. Higher aerobic fitness also means faster recovery and ability to perform more high intensity activities.

High intensity activities are of high importance for football teams. It was determined that successful teams performed more high intensity activities than unsuccessful teams when they had the ball in possession during the match [40]. CV was the best predictor of total covered distance, high intensity and sprint running in the current study. According to these findings, it may be said that high aerobic fitness level is related with the ability to recover quickly between high-intensity activities. However, ASR had negative effect on aerobic activities such as walking and total covered distance. This result may show that the aerobic contribution to exercise is lower in athletes with high ASR. The aerobic contribution level is a key factor for faster recovery between high intensity activities in football. High repeated sprint performance is closely related to higher recovery capability. Furthermore, it was found that ADC was the best predictor of high intensity running and maximum running speed in our study. It may be concluded that ADC is closely related with high intensity runs as an anaerobic fitness parameter in football.

Conclusion

Consequently, the CV parameter is an indicator of aerobic performance during match. The ASR parameter represents a reserve between MAS and MSS values and is dependent on MAS level. Higher MAS value means higher aerobic endurance and more aerobic contribution to exercise. It may be said that ASR is negatively related to aerobic contribution to exercises during match. The statistical values indicate that ASR was negatively related to maximum running speed at the highest proportion during football match. The results obtained in our study indicated that the higher the ASR value, the lower the aerobic fitness level. It might therefore be stated that the level of aerobic endurance during a football match is positively related to CV and negatively related to ASR. It is recommended that football coaches make use of CV and ASR parameters when determining the intensity of aerobic endurance exercises.

Acknowledgements

This study was written by abridging Hamit CİHAN. No grants or financial aids were taken in this Project.

Financial support

There is no financial support.

Conflict of interest

The authors report no conflict of interest.

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Cite this article as:

Cihan H. An analysis of the relationship between critical velocity and anaerobic speed reserve with match running profile in footbal. *Pedagogy of Physical Culture and Sports,* 2022;26(6):353–363. https://doi.org/10.15561/26649837.2022.0601

Received: 26.09.2022
Accepted: 28.10.2022; Published: 30.12.2022