



The prediction of repeated sprint and speed endurance performance by parameters of critical velocity models in soccer

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Abstract

Purpose: The prediction of running anaerobic sprint test and 800 m performance by parameters of critical velocity was examined in this study.

Material: The participants of study were consisted of thirteen amateur soccer players (n=13, age=22.69±5.29 years, weight=72.46±6.32 kg, height=176.92±6.73 cm). The 800 and 2400 m running tests were performed for determination of critical velocity and anaerobic distance capacity. The critical velocity and anaerobic distance capacity were determined by three mathematical models (linear total distance, linear velocity, non-linear two parameter model). The repeated sprint and sprint endurance ability was determined by running anaerobic sprint test and 800 m running test. The simple and multiple linear regression analysis was used for prediction of dependent variables (running anaerobic sprint test and 800 m running performance) by independent variables (critical velocity and anaerobic distance capacity) of study. The correlation between variables was determined by Pearson correlation coefficient.

Results: It was found that anaerobic distance capacity was a significant predictor of running anaerobic sprint test and 800 m running performance (p<0.05). However, it was determined that critical velocity predicted significantly only time parameters of running anaerobic sprint test and 800 m test (p<0.05). Also, the parameters of 800 m test (except for average velocity) were significantly predicted by running anaerobic sprint test parameters (p<0.05).

Conclusions: It may be concluded that anaerobic distance capacity is an indicator of repeated sprint and speed endurance ability in soccer and may be used in improvement of sprint endurance performance.

Keywords: soccer, critical velocity, repeated sprint, speed endurance, sprint tests.

Introduction

The oxygen uptake of muscles may be accepted as important determinant of aerobic exercise performance and critical velocity (CV) or critical power parameter is closely related to it. It is indicated that the critical power is an important indicator of oxygen uptake ability during exercise [1]. The CV was originated from critical power concept. The critical power concept was firstly defined by Monod and Scherrer [2]. The critical power tests were consisted of a series of exhausting exercises on small muscle groups with different exercise intensities [2]. The critical power (slope of linear regression graph) and anaerobic work capacity (y-intercept of linear regression graph) parameters were yielded by the linear relationship between work (parameter determined by multiplied of power and time) and exhaustion time of test [4-6]. Then, test procedure was performed on cycle ergometer with different power values [3]. The CV and anaerobic distance capacity (ADC) were determined by a series tests performed on treadmill [7, 8]. The CV and ADC parameters corresponded to critical power and anaerobic work capacity parameters in critical power test [9, 10]. The CV is maximum running velocity sustained without fatigue and ADC is distance covered with anaerobic energy sources in muscles [9-11]. The aerobic fitness level of

athletes may be evaluated with CV and ADC parameters. The CV tests have various advantages at determination of aerobic fitness. The procedure of CV tests is simple and easy for aerobic performance measurement of athletes. The CV parameter was determined with distance, velocity and time parameters of two or more runnings. Also, the CV test protocol may be performed on treadmill or field.

The aerobic exercises such as walking, runnings with low intensity are frequently performed during soccer game frequently. On the other hand, it was indicated that the explosive power activities, explosive runnings, jumps, repeated sprints are important decisive of match performance [12-15]. The repeated sprint ability may relate to performance at last parts of soccer match observed fatigue. The anaerobic activities such as sprint may have high importance on critical moments of soccer match [16]. The anaerobic activities such as repeated sprints may be related to various performance parameters as CV and ADC. If the probable effects on anaerobic activities (repeated sprint and 800 m) of CV and ADC parameters is determined, the anaerobic activities of soccer players may be organized in the light of CV and ADC parameters. Many studies are available in literature about anaerobic activities such as repeated sprint and 800 m running. However, it has been seen that few studies in literature have focused on relationship between CV test parameters and anaerobic activities such as repeated sprint and 800

m. The aim of this study was to predict repeated sprint and 800 m performances by CV and ADC parameters.

Material and Methods

Participants

The thirteen amateur soccer players (n=13, age=22.69±5.29 years, weight=72.46±6.32 kg, height=176.92±6.73 cm) participated in the study. The participants consisted of players playing in a soccer team competing regional amateur league of Turkey and performing soccer trainings 1.5 hours for five days of a week regularly. The participants were informed about study and they signed informed voluntary consent form. The study was performed according to principles of Helsinki Declaration.

Research Design

Data Collection

800 m and 2400 m Running Tests

The 800 and 2400 m running tests were performed in order to determine CV and ADC [17]. The tests were performed on synthetic grass soccer pitch at same hour of day to eliminate effects of circadian rhythm. The high intensity exercises were not performed within 24 hours before the tests. The measurements were performed at pre-season preparation term. The distance of tests was marked with training cones. The 800 m test was firstly performed firstly. The players performed ten minutes warm-up and stretching exercises before the test. Each player entered the test individually. The players tried to run 800 m distance in shortest time with maximum effort (with 100% exercise intensity). The verbal encouragement was given to players by researchers during test. The test was finished when 800 m distance was covered by players. The test time was measured by wireless photocell system (Witty, Microgate, Bolzano, Italy). The test time was recorded in second unit with 0.01 precision. After three days from 800 m test, 2400 m test was performed by players. The procedure of 2400 m test was similar to the 800 m test. The test time of players was measured similarly. After the tests, the players performed warm-down exercises.

Running Anaerobic Sprint Test (RAST)

RAST was a test used for determination of repeated sprint ability [18, 19]. The RAST was consisted of six 35 m sprints performed with 10 seconds rest interval. The test was carried out on synthetic grass soccer pitch at same hour of day after three days from 2400 m running test. The 35 m test track was set on soccer pitch. The gates of wireless photocell system (Witty, Microgate, Bolzano, Italy) were placed at start and finish point of 35 m test track. The players performed warm-up and stretching exercises before test. The players performed six 35 m sprints with 10 seconds recovery interval between each sprint. The verbal motivation was given to players during test. The time of six sprints was recorded in second unit with 0.01 precision. The test parameters were determined as follow:

- Power (watt)= Weight (kg) x Distance (m)² ÷ Time³(sec) [20],
- Minimum power (watt): The lowest power value of

six sprints,

- Peak power (watt): The highest power value of six sprints,
- Average power (watt): The mean power value of six sprints,
- Fatigue index (watt/sec) = (Maximum power (watt)- Minimum power (watt)) ÷ Total time of 6 sprints (sec) [18],
- Average test time (sec): Mean of six sprint times,
- Total test time (sec): Sum of six sprints times,
- Velocity (km/h)= Sprint distance (km) ÷ Sprint time (h),
- Average velocity (km/h): Mean velocity of six sprints,
- Maximum velocity (km/h): The highest velocity of six sprints.

800 m Running Test

The 800 m test was carried out in order to determine relationship between 800 m performance and RAST, CV and ADC parameters. After three days from RAST, 800 m test was performed at same hour of day on synthetic grass soccer pitch. Test track was prepared on soccer pitch. After warm-up and stretching exercises, players started the test. Each player performed the test individually. The players ran with maximum effort and covered 800 m distance at shortest time. Test time was determined by wireless photocell system (Witty, Microgate, Bolzano, Italy). The 800 m test time was recorded in sec unit with 0.01 precision.

Determination of Critical Velocity (CV) and Anaerobic Distance Capacity (ADC)

The three mathematical models were used for determination of CV and ADC. These mathematical models consisted of linear and non-linear regression models. The time (t), distance (D) and velocity (V) at 800 and 2400 m tests were used in three mathematical models. The first mathematical model was linear total distance (Lin-TD) model. The Lin-TD model was derived from linear regression analysis between D and t parameters of 800 and 2400 m tests for each participant [20-27]:

$$D = ADC + CV \times t$$

In Lin-TD model, the regression slope was CV and y-intercept of distance-time relationship (y-intercept of regression line) was ADC.

The second mathematical model was linear velocity (Lin-V) model. The Lin-V model was consisted of regression analysis between V and inverse of time (1/t) of 800 and 2400 m tests and the 1/t value were used in model to be converted to linear of hyperbolic relationship between V and t [23-25, 27-31]:

$$V = ADC \times (1/t) + CV$$

In Lin-V model, the regression slope was ADC and y-intercept of V – 1/t relationship (y-intercept of regression line) was CV.

The third mathematical model was known as non-linear model with 2-parameter (Non-2). The equation

of Lin-V model was solved for t parameter and the hyperbolic relationship between V and t was indicated by Non-2 model [27-30, 32-34]:

$$t = \text{ADC} / (V - \text{CV})$$

Statistical Analysis

The descriptive statistics of study were presented as mean ± standard deviation and range (minimum-maximum) values (table 1). The CV and ADC parameters of each player were determined by linear and nonlinear regression analysis. The Shapiro Wilk test was utilised to examine normality of data. The simple scatter graphs were examined for determination of linearity between dependent and independent variables at regression models. The multicollinearity between independent variables of regression models was examined by VIF (variance inflation factor). The regression models were designed in accordance with ideal VIF. The simple and multiple linear regression analysis was used for prediction of dependent variables (RAST and 800 m test parameters) by independent variables of study (CV and ADC). All data were analysed in the SPSS package program (IBM SPSS 22.0. Armonk, NY: IBM Corp.). The significance level at statistical analysis was performed as p<0.05.

Results

Table 1. The Descriptive Statistics of Test Parameters

Tests	Parameters	Mean ± SD	Range	
CV Test (n=13)	Lin-TD Model	CV (km/h)	12.93 ± 0.61	11.95 – 14.00
		ADC (km)	0.22 ± 0.03	0.15 – 0.28
	Lin-V Model	CV (km/h)	12.96 ± 0.61	11.93 – 14.01
		ADC (km)	0.22 ± 0.03	0.16 - 0.28
	Non-2 Model	CV (km/h)	12.96 ± 0.62	11.98 – 14.01
		ADC (km)	0.22 ± 0.03	0.15 – 0.28
RAST Test (n=13)		t _(average) (sec)	5.23 ± 0.27	4.87 – 5.81
		t _(total) (sec)	31.40 ± 1.64	29.20 – 34.85
		V _(average) (km/h)	24.20 ± 1.22	21.75 – 25.95
		V _(max) (km/h)	26.08 ± 1.35	23.38 – 27.88
		Min. power _(relative) (watt/kg)	7.04 ± 1.06	5.27 – 8.92
		Min. power (watt)	509.89 ± 92.50	393.57 – 713.31
		Max. power _(relative) (watt/kg)	10.94 ± 1.66	7.82 – 13.27
		Max. power (watt)	791.76 ± 135.62	589.85 – 1061.23
		Mean power _(relative) (watt/kg)	8.82 ± 1.29	6.36 – 10.78
		Mean power (watt)	638.38 ± 108.38	479.26 – 862.42
800 m running test (n=13)		Fatigue index (watt/sec)	9.05 ± 2.42	5.53 – 14.12
		t (sec)	155.00 ± 9.35	145.00 – 179.00
		V _(average) (km/h)	18.30 ± 1.43	15.00 – 20.00
		V _(max) (km/h)	24.50 ± 2.33	19.60 – 27.70

Note. Lin-TD: Linear Total Distance Model, Lin-V: Linear Velocity Model, Non-2: Nonlinear 2-parameter Model, CV: Critical velocity, ADC: Anaerobic Distance Capacity, RAST: Repeated Anaerobic Sprint Test, t: test time, t_(average) = average test time, t_(total) = total test time, V: velocity, V_(average) = average velocity, V_(max) = maximum velocity, min. power_(relative) = relative minimum power of six 35 m. runnings, min. power = salt minimum power of six 35 m. runnings, max. power_(relative) = relative maximum power of six 35 m. runnings, max. power = salt maximum power of six 35 m. runnings, mean power_(relative) = relative mean power of six 35 m. runnings, mean power = salt mean power of six 35 m. runnings, fatigue index = fatigue index of six 35 m. runnings.

There was no significant correlation between CV values and RAST parameters in Table 2 (p>0.05). On the other hand, it was found that the ADC values correlated significantly with RAST parameters (p<0.05).

According to analysis results in Table 3, it was seen that CV and ADC parameters correlated significantly with time and maximum velocity at 800 m test (p<0.05). It was found no significant correlation between average velocity at 800 m test and CV, ADC parameters (p>0.05).

According to results of correlation analysis between RAST and 800 m test parameters in Table 4, there was a significant correlation between RAST parameters and time and maximum velocity at 800 m test (p<0.05). It was found that there was no significant correlation between average velocity at 800 m test and RAST parameters (p>0.05).

In Table 5, the analysis result indicated prediction of the RAST parameters by CV and ADC parameters. The both CV and ADC predicted significantly time parameters of RAST (t_{verage} and t_{total}) (p<0.05). The velocity and power parameters of RAST (V_{average}, V_{max}, minimum, maximum and mean power) were significantly predicted by ADC merely (p<0.05). Also, it was found that the ADC of Lin-TD and Non-2 model was a significant predictor of fatigue index value of RAST (p<0.05).

According to results in Table 6, the parameters of time and maximum velocity at 800 m test were significantly

Table 2. Pearson Correlation Analysis Results Between CV, ADC and RAST Parameters

Model	Parameters	Correlation	RAST						Fatigue index (watt/sec)	
			t _(average) (sec)	t _(total) (sec)	V _(average) (km/h)	V _(max) (km/h)	Min. power _(relative) (watt)	Max. power _(relative) (watt)		Mean power _(relative) (watt)
Lin-TD	CV (km/h)	r	-0.500	-0.501	0.480	0.411	0.438	0.384	0.457	0.135
		p	0.082	0.081	0.097	0.163	0.135	0.195	0.116	0.661
	ADC (km)	r	-0.635	-0.637	0.629	0.671	0.594	0.666	0.621	0.593
		p	0.020*	0.019*	0.021*	0.012*	0.032*	0.013*	0.024*	0.033*
Lin-V	CV (km/h)	r	-0.504	-0.505	0.485	0.433	0.424	0.407	0.463	0.199
		p	0.079	0.078	0.093	0.140	0.149	0.167	0.111	0.515
	ADC (km)	r	-0.696	-0.697	0.693	0.679	0.721	0.675	0.688	0.506
		p	0.008*	0.008*	0.009*	0.011*	0.005*	0.011*	0.009*	0.078
Non-2	CV (km/h)	r	-0.504	-0.505	0.485	0.414	0.446	0.388	0.462	0.137
		p	0.079	0.078	0.093	0.160	0.127	0.191	0.112	0.656
	ADC (km)	r	-0.633	-0.635	0.626	0.668	0.596	0.662	0.618	0.596
		p	0.020*	0.020*	0.022*	0.013*	0.032*	0.014*	0.024*	0.031*

Note. * p<0.05

Table 3. Pearson Correlation Analysis Results Between CV, ADC and 800 m Test Parameters

Model	Parameters	Correlation	800 m test		
			t (sec)	V _(average) (km/h)	V _(max) (km/h)
Lin-TD	CV (km/h)	r	-0.452	-0.064	0.555
		p	0.121	0.837	0.049*
	ADC (km)	r	-0.770	0.510	0.681
		p	0.002*	0.075	0.010*
Lin-V	CV (km/h)	r	-0.475	-0.071	0.565
		p	0.101	0.817	0.044*
	ADC (km)	r	-0.782	0.499	0.726
		p	0.002*	0.082	0.005*
Non-2	CV (km/h)	r	-0.451	-0.074	0.560
		p	0.122	0.810	0.047*
	ADC (km)	r	-0.762	0.493	0.686
		p	0.002*	0.087	0.010*

Note. *p<0.05

predicted by both CV and ADC (p<0.05). Also, it was seen that CV and ADC were not significant predictors of average velocity at 800 m test (p>0.05).

The results in Table 7 indicated that the RAST parameters were significant predictors of time and maximum velocity at 800 m test (p<0.05). The average velocity at 800 m test was not significantly predicted by RAST parameters (p>0.05). On the other hand, it was found that the fatigue index parameter of RAST predicted significantly time of 800 m test merely (p<0.05).

Discussion

The CV and ADC parameters are products of linear relationship between distance and time of exercise. Also, these parameters are determined from linear relationship between velocity and time⁻¹ or other non-linear mathematical models. The CV and ADC were frequently investigated in various studies. It was found that CV correlated with maximal aerobic velocity and maximum oxygen uptake [35, 36]. The significant and high correlation (r = 0.80-0.93 range, p<0.01) between CV of five mathematical models and one hour running performance indicated relationship between CV and

Table 4. Pearson Correlation Analysis Results Between RAST and 800 m Test Parameters

RAST Parameters	Correlation	800 m test		
		t (sec)	V _(average) (km/h)	V _(max) (km/h)
t _(average) (sec)	r	0.806	-0.341	-0.746
	p	0.001*	0.254	0.003*
t _(total) (sec)	r	0.807	-0.342	-0.745
	p	0.001*	0.253	0.003*
V _(average) (km/h)	r	-0.799	0.335	0.725
	p	0.001*	0.263	0.005*
V _(max) (km/h)	r	-0.815	0.438	0.698
	p	0.001*	0.135	0.008*
Min. power _(relative) (watt)	r	-0.698	0.197	0.762
	p	0.008*	0.519	0.002*
Max. power _(relative) (watt)	r	-0.804	0.434	0.678
	p	0.001*	0.139	0.011*
Mean power _(relative) (watt)	r	-0.790	0.330	0.705
	p	0.001*	0.271	0.007*
Fatigue index (watt/sec)	r	-0.661	0.420	0.387
	p	0.014*	0.153	0.191

Note. *p<0.05

Table 5. The Regression Analysis of Effect on RAST Parameters of CV and ADC as Predictor Variables

Dependent Variable	Model	Predictor Variables	B	Standard Error	β	t	p	R	R ²	Standard Error of Estimate
t _(average) (sec)	Model-1	Constant	8.895	1.146		7.764	0.000*			
		Lin-TD-CV	-0.205	0.086	-0.464	-2.371	0.039*	0.786	0.618	0.184
		Lin-TD-ADC	-4.543	1.462	-0.608	-3.107	0.011*			
	Model-2	Constant	8.904	1.062		8.385	0.000*			
		Lin-V-CV	-0.192	0.081	-0.435	-2.386	0.038*	0.819	0.671	0.171
		Lin-V-ADC	-5.328	1.496	-0.649	-3.561	0.005*			
Model-3	Constant	8.918	1.145		7.787	0.000*				
	Non-2-CV	-0.205	0.086	-0.467	-2.384	0.038*	0.786	0.618	0.184	
	Non-2-ADC	-4.611	1.494	-0.604	-3.086	0.012*				
t _(total) (sec)	Model-1	Constant	53.472	6.869		7.785	0.000*			
		Lin-TD-CV	-1.235	0.518	-0.465	-2.385	0.038*	0.788	0.621	1.107
		Lin-TD-ADC	-27.414	8.765	-0.610	-3.128	0.011*			
	Model-2	Constant	53.527	6.360		8.417	0.000*			
		Lin-V-CV	-1.160	0.483	-0.436	-2.403	0.037*	0.821	0.674	1.027
		Lin-V-ADC	-32.149	8.961	-0.651	-3.588	0.005*			
Model-3	Constant	53.607	6.867		7.807	0.000*				
	Non-2-CV	-1.237	0.516	-0.468	-2.397	0.037*	0.788	0.621	1.108	
	Non-2-ADC	-27.818	8.961	-0.606	-3.104	0.011*				
V _(average) (km/h)	Model-1	Constant	8.308	5.315		1.563	0.149			
		Lin-TD-CV	0.881	0.400	0.445	2.201	0.052	0.770	0.592	0.857
		Lin-TD-ADC	20.204	6.783	0.602	2.979	0.014*			
	Model-2	Constant	8.232	4.911		1.676	0.125			
		Lin-V-CV	0.826	0.373	0.416	2.216	0.051	0.807	0.651	0.793
		Lin-V-ADC	23.880	6.920	0.648	3.451	0.006*			
Model-3	Constant	8.200	5.313		1.543	0.154				
	Non-2-CV	0.884	0.399	0.448	2.214	0.051	0.769	0.592	0.857	
	Non-2-ADC	20.494	6.934	0.598	2.956	0.014*				
V _(max) (km/h)	Model-1	Constant	10.150	5.918		1.715	0.117			
		Lin-TD-CV	0.817	0.446	0.372	1.832	0.097	0.767	0.588	0.954
		Lin-TD-ADC	24.112	7.551	0.649	3.193	0.010*			
	Model-2	Constant	9.934	5.879		1.690	0.122			
		Lin-V-CV	0.801	0.446	0.365	1.796	0.103	0.770	0.593	0.949
		Lin-V-ADC	26.126	8.283	0.640	3.154	0.010*			
Model-3	Constant	10.060	5.932		1.696	0.121				
	Non-2-CV	0.818	0.446	0.374	1.834	0.096	0.765	0.585	0.957	
	Non-2-ADC	24.464	7.741	0.645	3.160	0.010*				

Table 5 (continued)

Dependent Variable	Model	Predictor Variables	B	Standard Error	β	t	p	R	R ²	Standard Error of Estimate
Min. power _(relative) (watt/kg)	Model-1	Constant	-5.692	5.047		-1.128	0.286			
		Lin-TD-CV	0.698	0.380	0.404	1.835	0.096	0.718	0.516	0.813
		Lin-TD-ADC	16.677	6.440	0.571	2.590	0.027*			
	Model-2	Constant	-5.662	4.335		-1.306	0.221			
		Lin-V-CV	0.606	0.329	0.351	1.843	0.095	0.801	0.642	0.700
		Lin-V-ADC	21.951	6.109	0.684	3.593	0.005*			
	Model-3	Constant	-5.885	5.006		-1.176	0.267			
		Non-2-CV	0.706	0.376	0.411	1.877	0.090	0.723	0.523	0.808
		Non-2-ADC	17.022	6.533	0.570	2.606	0.026*			
Max. power _(relative) (watt/kg)	Model-1	Constant	-7.583	7.459		-1.017	0.333			
		Lin-TD-CV	0.928	0.562	0.346	1.652	0.130	0.750	0.562	1.202
		Lin-TD-ADC	29.310	9.518	0.645	3.080	0.012*			
	Model-2	Constant	-7.904	7.383		-1.071	0.310			
		Lin-V-CV	0.911	0.560	0.339	1.627	0.135	0.755	0.570	1.192
		Lin-V-ADC	31.895	10.403	0.639	3.066	0.012*			
	Model-3	Constant	-7.706	7.473		-1.031	0.327			
		Non-2-CV	0.931	0.562	0.348	1.657	0.129	0.748	0.560	1.206
		Non-2-ADC	29.740	9.753	0.641	3.049	0.012*			
Mean power _(relative) (watt/kg)	Model-1	Constant	-7.291	5.811		-1.255	0.238			
		Lin-TD-CV	0.883	0.438	0.422	2.016	0.071	0.750	0.563	0.937
		Lin-TD-ADC	21.101	7.416	0.596	2.845	0.017*			
	Model-2	Constant	-7.413	5.362		-1.383	0.197			
		Lin-V-CV	0.825	0.407	0.394	2.027	0.070	0.792	0.627	0.866
		Lin-V-ADC	25.131	7.555	0.646	3.326	0.008*			
	Model-3	Constant	-7.414	5.809		-1.276	0.231			
		Non-2-CV	0.887	0.437	0.426	2.031	0.070	0.750	0.562	0.938
		Non-2-ADC	21.396	7.581	0.592	2.822	0.018*			
Fatigue index (watt/sec)	Model-1	Constant	-4.682	13.152		-0.356	0.729			
		Lin-TD-CV	0.392	0.991	0.100	0.396	0.701	0.602	0.362	2.121
		Lin-TD-ADC	38.975	16.783	0.588	2.322	0.043*			
	Model-2	Constant	-6.274	13.978		-0.449	0.663			
		Lin-V-CV	0.574	1.061	0.146	0.542	0.600	0.527	0.277	2.257
		Lin-V-ADC	35.738	19.695	0.491	1.815	0.100			
	Model-3	Constant	-4.883	13.100		-0.373	0.717			
		Non-2-CV	0.392	0.985	0.101	0.398	0.699	0.605	0.366	2.115
		Non-2-ADC	39.983	17.096	0.590	2.339	0.041*			

Note. *p<0.05

aerobic exercise performance [37]. It was reported that CV was significantly correlated with both maximal lactate steady state and onset of blood lactate [38]. Also, performance at 3000 m running was closely related to CV parameter [39]. These findings support that CV is an aerobic performance indicator. In our study, it was determined that CV parameter of three models correlated with maximum velocity at 800 m test ($p<0.05$) (table 3). However, it was seen that the significance level of correlation was not high (0.44-0.49 range of p value). In this context, it may be said that the 800 m test is an anaerobic test dominantly and the contribution on test performance of aerobic fitness is low. Simões et al. [40] found a significant correlation between CV and 500 m,

3 and 10 km running velocity and this result showed parallelism to correlation between CV and maximum velocity at 800 m test in our study. Particularly, the findings of our study were similar to correlation between CV and 500 m running velocity in mentioned study. This relationship in mentioned study is remarkable although the anaerobic contribution to 500 m performance is higher than 800 m test. Similarly, Bosquet et al. [41] reported that the 40-62 % of variance in velocity at 800 m running was explained by CV estimates of five mathematical models. The CV and ADC estimates of three models used in our study predicted significantly maximum velocity at 800 m test and both parameters explained 73-76.8 % of total variance in mentioned variable (table 6). It was seen that

Table 6. The Regression Analysis of Effect on 800 m Test Parameters of CV and ADC as Predictor Variables

Dependent Variable	Model	Predictor Variables	B	Standart Error	β	t	p	R	R ²	Standard Error of Estimate
t (sec)	Model-1	Constant	277.148	31.199		8.883	0.000*	0.871	0.759	5.032
		Lin-TD-CV	-6.160	2.351	-0.408	-2.621	0.026*			
		Lin-TD-ADC	-190.976	39.813	-0.746	-4.797	0.001*			
	Model-2	Constant	278.619	30.667		9.085	0.000*			
		Lin-V-CV	-6.000	2.327	-0.396	-2.579	0.027*			
		Lin-V-ADC	-207.828	43.209	-0.739	-4.810	0.001*			
	Model-3	Constant	276.729	32.118		8.616	0.000*			
		Non-2-CV	-6.101	2.414	-0.405	-2.527	0.030*			
		Non-2-ADC	-192.589	41.915	-0.737	-4.595	0.001*			
V _(average) (km/h)	Model-1	Constant	16.620	8.354		1.990	0.075	0.519	0.269	1.347
		Lin-TD-CV	-0.218	0.629	-0.094	-0.347	0.736			
		Lin-TD-ADC	20.290	10.660	0.516	1.903	0.086			
	Model-2	Constant	17.214	8.363		2.058	0.067			
		Lin-V-CV	-0.293	0.635	-0.126	-0.462	0.654			
		Lin-V-ADC	22.165	11.783	0.513	1.881	0.089			
	Model-3	Constant	16.997	8.426		2.017	0.071			
		Non-2-CV	-0.242	0.633	-0.105	-0.383	0.710			
		Non-2-ADC	20.093	10.996	0.500	1.827	0.098			
V _(max) (km/h)	Model-1	Constant	-9.908	8.228		-1.204	0.256	0.854	0.730	1.327
		Lin-TD-CV	1.947	0.620	0.517	3.141	0.011*			
		Lin-TD-ADC	41.474	10.500	0.650	3.950	0.003*			
	Model-2	Constant	-10.023	7.615		-1.316	0.217			
		Lin-V-CV	1.861	0.578	0.493	3.221	0.009*			
		Lin-V-ADC	47.182	10.729	0.674	4.398	0.001*			
	Model-3	Constant	-10.215	8.060		-1.267	0.234			
		Non-2-CV	1.950	0.606	0.520	3.219	0.009*			
		Non-2-ADC	42.619	10.519	0.654	4.052	0.002*			

Note. *p<0.05

the finding of our study was similar to results of Bosquet et al. [41].

It was found that the time and distance values of test performed with 120 % of maximal oxygen uptake velocity were correlated with curvature constant (W' parameter corresponded to ADC) of Lin-TD and Lin-V models in professional young soccer players [42]. The ADC parameter was a significant predictor of the most parameters of RAST (table 5) and 800 m tests (table 6) in our study and this finding was in agreement with results of mentioned study. These findings show that the effect of ADC is too distinct in anaerobic exercises. Beck et al. [43] found high and significant correlation ($r = 0.68-0.83$ range, $p < 0.05$) between RAST power and maximum velocity parameters and times of short distance anaerobic running (50, m running) [43]. Also, the related study reported a significant correlation between mean power at RAST and time of 300 m running. However, it was determined that the correlation between ADC (constant curvature (W') in related study) and times of 50, 100 and 300 m runnings was not significant in mentioned study. It was found a significant relationship between 800 m performance and ADC in our study (table 3). The discrepancy of findings may be arisen from difference of

running distances (800 m v 50, 100 and 300 m) in these studies. It may be indicated that 800 m performance may be highly affected by ADC.

Chatzakis et al. [44] reported that there was a significant correlation between RAST minimum and mean power parameters and 300 and 1000 m running time in children and young adolescents. In mentioned study, it was reported that maximum power parameters of RAST were only correlated with 300 m running time. It was found that RAST parameters were significant predictors of time and maximum velocity at 800 m test in our study (table 7). The 800 m running test is dominantly anaerobic test. The parameters of RAST involving repeated explosive sprints are indicators of anaerobic exercises such as 800 and 1000 m running. However, maximum power parameter of RAST is the highest power in exercise. Therefore, it may be said that maximum power parameter of RAST may be more dominant in exercises requiring high contribution of anaerobic energy system such as 300 m running. Zagatto et al. [45] researched relationship RAST parameters and results of Hoff test (a soccer-specific test developed by Hoff et al. [46] for anaerobic fitness level in soccer players) in professional soccer players and found no significant correlation between test results. It was

Table 7. The Regression Analysis of Effect on 800 m Test Parameters of RAST Parameters as Predictor Variables

Dependent Variable	Model	Predictor Variables	B	Standard Error	β	t	p	R ²	Standard Error of Estimate
t (sec)	Model-1	Constant	10.394	32.047		0.324	0.752	0.650	5.781
		t(average)	27.613	6.112	0.806	4.518	0.001*		
	Model-2	Constant	10.753	31.875		0.337	0.742	0.651	5.770
		t(total)	4.593	1.014	0.807	4.531	0.001*		
	Model-3	Constant	302.458	33.557		9.013	0.000*	0.638	5.881
		V _(average)	-6.093	1.385	-0.799	-4.400	0.001*		
	Model-4	Constant	301.431	31.417		9.594	0.000*	0.664	5.659
		V(max)	-5.615	1.203	-0.815	-4.667	0.001*		
Model-5	Constant	198.001	13.460		14.711	0.000*	0.487	7.000	
	Min. power _(relative)	-6.108	1.892	-0.698	-3.229	0.008*			
Model-6	Constant	204.570	11.171		18.312	0.000*	0.646	5.809	
	Max. power _(relative)	-4.530	1.010	-0.804	-4.484	0.001*			
Model-7	Constant	205.360	11.902		17.254	0.000*	0.624	5.990	
	Mean power _(relative)	-5.709	1.336	-0.790	-4.273	0.001*			
Model-8	Constant	178.091	8.165		21.811	0.000*	0.437	7.332	
	Fatigue index	-2.549	0.873	-0.661	-2.920	0.014*			
V _(average) (km/h)	Model-1	Constant	27.722	7.828		3.542	0.005*	0.116	1.412
		t(average)	-1.798	1.493	-0.341	-1.204	0.254		
	Model-2	Constant	27.710	7.798		3.553	0.005*	0.117	1.411
		t(total)	-0.299	0.248	-0.342	-1.207	0.253		
	Model-3	Constant	8.790	8.076		1.088	0.300	0.112	1.415
		V _(average)	0.393	0.333	0.335	1.180	0.263		
	Model-4	Constant	6.220	7.499		0.829	0.425	0.191	1.350
		V(max)	0.464	0.287	0.438	1.614	0.135		
Model-5	Constant	16.439	2.832		5.805	0.000*	0.039	1.472	
	Min. power _(relative)	0.265	0.398	0.197	0.667	0.519			
Model-6	Constant	14.195	2.603		5.453	0.000*	0.188	1.353	
	Max. power _(relative)	0.376	0.235	0.434	1.597	0.139			
Model-7	Constant	15.074	2.818		5.349	0.000*	0.109	1.418	
	Mean power _(relative)	0.367	0.316	0.330	1.159	0.271			
Model-8	Constant	16.049	1.518		10.573	0.000*	0.177	1.363	
	Fatigue index	0.249	0.162	0.420	1.537	0.153			
V _(max) (km/h)	Model-1	Constant	57.869	8.979		6.445	0.000*	0.557	1.619
		t(average)	-6.372	1.712	-0.746	-3.721	0.003*		
	Model-2	Constant	57.696	8.967		6.434	0.000*	0.555	1.623
		t(total)	-1.057	0.285	-0.745	-3.707	0.003*		
	Model-3	Constant	-8.873	9.564		-0.928	0.373	0.526	1.676
		V _(average)	1.379	0.395	0.725	3.494	0.005*		
	Model-4	Constant	-6.765	9.672		-0.699	0.499	0.488	1.742
		V(max)	1.199	0.370	0.698	3.237	0.008*		
Model-5	Constant	12.801	3.033		4.220	0.001*	0.580	1.577	
	Min. power _(relative)	1.662	0.426	0.762	3.898	0.002*			
Model-6	Constant	14.077	3.439		4.093	0.002*	0.460	1.788	
	Max. power _(relative)	0.952	0.311	0.678	3.063	0.011*			
Model-7	Constant	13.304	3.431		3.877	0.003*	0.497	1.727	
	Mean power _(relative)	1.269	0.385	0.705	3.295	0.007*			
Model-8	Constant	21.130	2.500		8.453	0.000*	0.150	2.244	
	Fatigue index	0.372	0.267	0.387	1.392	0.191			

Note. *p<0.05

indicated that the Hoff test was used for measurement of aerobic fitness level with soccer specific exercises (dribbling and activities with ball) [46]. The RAST power parameters were not significantly correlated with CV in our study (table 2) and this finding sustained the results of Zagatto et al. [45].

It was indicated that 20 m sprint time was a powerful predictor of total time and sprint decrement score at RAST test in national level soccer players [47]. Similarly, the ADC parameter was a significant predictor of RAST parameters in our study (table 5). The sprint time decrement index (score developed by Glaister et al. [48]) of RAST had significant correlation with maximum oxygen uptake (VO_{2max}) in low and high level VO_{2max} groups (positive correlation for low level VO_{2max} group, negative correlation for high level VO_{2max} group) but no significant correlation was found for medium level VO_{2max} group [49]. There was no correlation between CV and fatigue index of RAST in our study (table 2) and this finding drew parallelism with the correlation result of medium level VO_{2max} group in mentioned study. The decrement index used in study of Alizadeh et al. [49] was different from fatigue index in our study and this difference might cause discrepancy in results of two studies. Keir et al. [50] indicated that contribution of aerobic metabolism in RAST was higher than Wingate test although there was no significant difference between VO_{2max} values of two tests. There was no comparison between tests in our study and it was not seen a significant correlation between CV and RAST parameters (table 2). The mentioned study has focused on comparison of RAST and Wingate tests and interpreted aerobic metabolism effects on tests by VO_{2max} graphs. Our study was based on prediction of RAST parameters by CV and ADC and it was seen that the CV predicted significantly time parameters ($t_{(average)}$ and $t_{(total)}$) of RAST (table 5). The only CV effect on time parameters of RAST has sustained findings of Keir et al. [50] emphasizing aerobic contribution in RAST.

In study performed on professional soccer players, it was found that the correlation between RAST parameters and soccer match performance (total distance, maximum speed, high intensity and sprint count during soccer match) was not significant statistically [51]. Although the parameters determined in mentioned study were anaerobic activities except for total distance, the relationship between RAST and match parameters was not found by Redkva et al. [51]. Loures et al. [52] reported

that the anaerobic work capacity (equivalent of ADC) of soccer players under seventeen age did not correlate with power and fatigue index parameters of RAST but velocity parameters (mean and maximum velocity) had significant correlation with ADC. Similarly, it was determined a non-significant correlation between RAST and anaerobic running capacity (equivalent of ADC) in male futsal players [53]. Unlike finding of mentioned study, there was a significant correlation between all the RAST parameters and ADC (as an anaerobic parameter) in our study (table 2).

Conclusion

The CV and ADC parameters are yielded by linear and non-linear mathematical models. The CV is defined as aerobic fitness indices although ADC is an indicator of distance covered with anaerobic energy sources. The repeated sprint and sprint endurance ability is critical for performance in soccer involving repeated sprints. Therefore, RAST and 800 m performance that are indirect indicators of anaerobic performance is tried to predict by CV and ADC parameters in this study. It was found that ADC was a strong indicator of RAST performance. Also, it was seen that 800 m performance might be predicted by ADC and RAST parameters. CV parameter was not a significant predictor of RAST and 800 m performance except for time parameters of tests. It may be concluded that ADC may be used as an indicator of repeated sprint and sprint endurance performance while CV is a determinant of aerobic endurance performance. The CV and ADC parameters may be easily determined by simple methods without expensive measurement equipment and the performance of soccer players may be tracked by these parameters.

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Conflict of interest

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