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Maximum Aerobic Power Test for Soccer Players

Larissa B. Daros[1,2], Raul Osiecki[2], Antonio Carlos Dourado[3], Luiz Claudio R. Stanganélli[3], Andre M. Fornaziero[2], Ana C. V. Osiecki[3]

[1]Midwestern State University of Paraná, Guarapuava, Brazil, [2]Federal University of Parana / Center for the Study of Physical Performance, Curitiba, Brazil, [3]State University of Londrina / Sports Excellence Centre, Londrina, Brazil

ABSTRACT

Daros LB, Osiecki R, Dourado AC, Stanganélli LCR, Fornaziero AM, Osiecki ACV. Maximum Aerobic Power Test for Soccer Players. **JEPonline** 2012;15(2):80-89**.** The purpose of this study was to develop a maximum aerobic power test and an equation to estimate VO_2 max for soccer athletes. The proposed test consists of applying progressive, continuous, and maximal speed running that covers 80 m (1 lap), structured in a square (20 m x 20 m), where the athletes performs up to exhaustion. To measure velocity in field test, the CD test of Yo-yo endurance II proposed by Bangsbo (1996) was used. A maximal treadmill test was compared to the field test. Twenty-four soccer athletes were evaluated. The results showed no significant difference between treadmill test and the field test for determining VO_2 max (treadmill 50.19±5.09 and field 48.55±6.56; $P<0.077$). A high correlation was found between field VO_2 max with the distance covered in the field ($r=0.768$; $P<0.000$) and with the maximum speed reached in the field test ($r=0.737$; $P<0.000$). Thus, it was possible to establish two predictive equations through variables of distance covered and maximum speed reached. It is reasonable to conclude that the proposed field test can be used as an easy and useful tool for coaches and trainers, and should be applied to athletes during a competitive season.

Key Words: Field Test; Prediction of VO_2 max, Aerobic Power

INTRODUCTION

The physiological demands of a football game are those of intermittent and high intensity efforts, with high energy expenditure (18,24). Aerobic power is an important variable in this context because it acts in the recovery of such efforts, enabling a more effective participation of athletes during the match (3,4,13,24).

There is considerable agreement that the maximum value for uptake, transport, and use of oxygen is a good indicator of the functioning of the respiratory, cardiovascular and musculoskeletal systems. This is one of the reasons why research has shown great interest in the determination of VO_2 max, in a direct or indirect way, facilitating the understanding of physiological aspects related to performance during matches.

The procedure that is considered the "gold standard" in the evaluation of VO_2 max requires the use of metabolic equipment to measure the pulmonary gas exchange (CO_2 and O_2) during maximal tests on either a treadmill or a cycle ergometer. However, this method of assessment has significant practical limitations, such as the complexity of the equipment and the time required for the evaluation of all athletes on a team. In addition, tests performed on exercise ergometers do not directly replicate the movements and situations of a match, so there is no great motor specificity (6). Field tests specific for soccer are popular among coaches because of the simplicity, validity, and minimal use of equipment (4,20,27).

In this context, scientific research seeks to investigate alternatives to the assessment of VO_2 max in a more practical way regarding the daily activities of soccer teams. Thus, equations have been developed to estimate this variable from simple measures such as distance traveled, speed attained, time taken, maximum heart rate recorded during the test, thus optimizing their assessment in soccer teams. Therefore, the purpose of this study was to propose a test performed on the field that allows for the prediction of VO_2 max in juvenile and junior soccer athletes. This new protocol is progressive, continuous, and of maximum effort. The proposed protocol and related equation estimates VO_2 max based on the athlete's performance during the test and under variables such as those of time or distance.

METHODS

Experimental Approach to the Problem

This study is a correlational and descriptive research in the sense that it explores the relationships between variables. It was designed to establish the degree of relationship between the maximum aerobic power test proposed for field testing with the treadmill aerobic power test performed in the laboratory and the associations of these two tests with VO_2 max, heart rate maximum (HR max), respiratory exchange ratio (RER), expired ventilation (V_E), distance covered, total time, maximum speed, and final lactate. Test sessions took place over three separate days, with the participation of the subjects randomly distributed. The test sessions consisted of: (a) treadmill test and (b) field test.

Recently, several authors have emphasized the importance of expressing the physiological variables of soccer players (7,8,12,19,26). For this reason, we proposed a test to evaluate the maximum aerobic power of the player through a specific field test, using the variables established in the field for subsequent regression analysis.

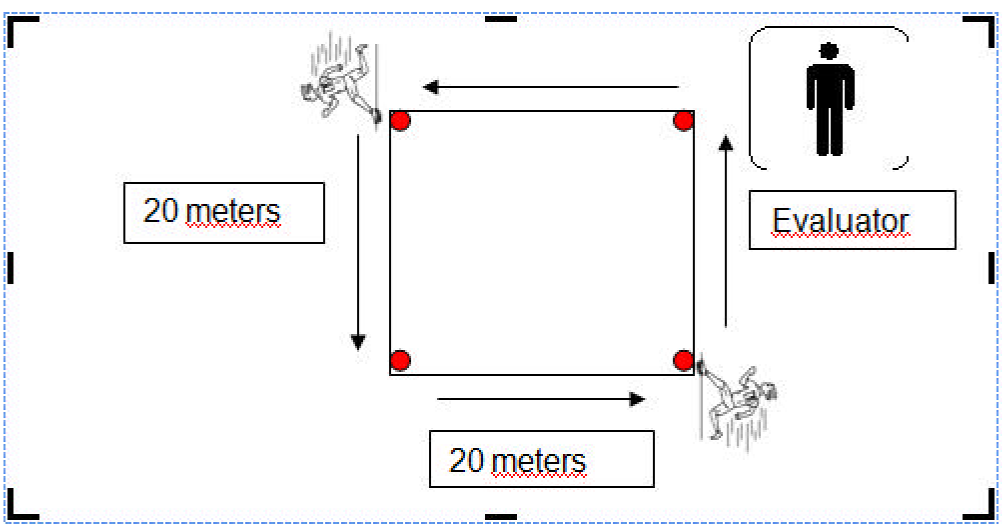
Subjects
The sample consisted of 24 young soccer players juvenile and junior categories aged 16.66 ± 1.49 yrs; body weight of 71.5 ± 8, 28 kg, height of 177.07 ± 0.82 cm, and BMI of 22.74 ± 1.28. All athletes were practitioners of the sport for at least 4 yrs. During the assessments, they were in full competitive activity. All subjects were informed about the goals and procedures of the study, and those who agreed to take part signed an informed consent form. This form, as well as the study in its entirety, was approved by the Ethics Committee of the Midwestern State University of Paraná.

Procedures
All subjects underwent two trials for the direct determination of VO_2 max; one was on a treadmill and the other on the soccer field. To minimize the changes of the circadian cycle, all measurements were performed in the morning, and the order for testing was randomized. The mean temperature and relative humidity during the laboratory tests were 23°C and 55%, respectively. Regarding the field tests, the values were 19.5°C for temperature and 77% for relative humidity.

The maximum progressive laboratory test was carried out on a motorized treadmill (ATL Inbramed 10200, Porto Alegre, Brazil), starting at 8 $km{\cdot}h^{-1}$ with speed increments of 1 $km{\cdot}h^{-1}$ every minute. Immediately after the athlete reached voluntary exhaustion, he underwent an active recovery lasting 3 min at a speed of 7 $km{\cdot}h^{-1}$. Throughout each test, the treadmill was set with a slope of 1%.

Regarding the field trials, the protocol defined by the field test consisted of a progressive and maximal running test with a total distance of 80 m, in the shape of a square of 20 m (see Figure 1). The execution speed of the test was determined by sound beeps similar to those of the Yo-Yo test of Endurance Level 2 (2), with initial velocity of 11.5 $km{\cdot}h^{-1}$ and load increments of 0.5 $km{\cdot}h^{-1}$ every minute, admitting that the Yo-Yo Endurance Test Level 2 aims to estimate the VO_2 max in well trained players in an attempt to shorten the evaluation time (7). In each corner of the square there was a cone, which should be circumvented by the athlete at the time of each beep. The test was always performed counterclockwise and stopped if the athlete did not reach the vertices for two consecutive times in trying to get around the cone at the time of the sound beep. The distance, maximum speed, and total time of each subject were recorded.

Figure 1. Proposed Field Test (20 x 20 m).



Total distance of a lap = 80 Meters

In both tests, all individuals were equipped with a portable ergospirometer that evaluates the data using a breath-by-breath measure (Cosmed, $K4B^2$, Rome, Italy). After completion of all tests, data were filtered and values averaged every 15 secs to adjust the performance curves during the tests. A telemetry system provided the values for oxygen uptake (VO_2), carbon dioxide production (VCO_2), expired ventilation (V_E), respiratory exchange ratio (RER) and heart rate (HR).

Analysis of blood lactate was performed after 3 min of the end of both tests. A disposable lancet was used, and 25 µl of blood were removed from the subject's earlobe through heparinized capillary tube. It was immediately transferred to an Eppendorf containing 50 µl of Sodium Fluoride (1%). The samples were properly preserved at -80°C and, then, analyzed in a specific lactate analyzer (Yellow Springs, 1500L, Ohio, USA).

Statistical Analyses

The data were analyzed using descriptive measures of central tendency (mean and standard deviation). The Student's t-test for paired samples was used to verify the existence of differences between the treadmill test and field test. To verify the relationship between the results obtained in both tests, the Pearson's correlation coefficient was used. The variables used as criteria to establish the regression equation were the field variables. To determine the prediction equation of VO_2 max using the field test, a simple linear regression was performed. All results were analyzed using PASW version 18.0 for Windows, with significance level of $P<0.05$.

RESULTS

Table 1 shows the results as mean and standard deviation, minimum, maximum, and the t value between the physiological variables in the field test (F) and the treadmill test (T). Most of the variables did not differ significantly between the treadmill test and field test. Only the values of distance (2307.5 ± 458.74 m, 1773.33 ± 334.49 m), total test time (10.49 ± 1.36 min, 7.72 ± 1.36 min), and maximum speed reached at the end of the test (18.04 ± 1.42 $km \cdot h^{-1}$, 15.10 ± 0.64 $km \cdot h^{-1}$) were significantly ($P<0.000$) different between the treadmill test and the field test, respectively. This may have occurred because the initial velocity of the field test (11.5 $km \cdot h^{-1}$) was greater than the initial velocity in the treadmill test (8 $km \cdot h^{-1}$).

Regarding the variables HR max (191.20 ± 7.02 $beats \cdot min^{-1}$, 191.79 ± 6.59 $beats \cdot min^{-1}$, $P<0.694$), RER (1.30 ± 0.09, 1.31 ± 1.10, $P<0.595$), V_E (138.25 ± 19.92 $mL \cdot min^{-1}$, 135.30 ± 14.97 $mL \cdot min^{-1}$, $P<0.408$), and final lactate (9.95 ± 2.68 mmol/l, 10.01 ± 2.14 mmol/l, $P<0.921$), they did not show statistically significant differences between the treadmill test and the field test, respectively.

According to the results it can be seen in Table 2 that the correlation found for VO_2 max in the field and treadmill test is considered high ($r = 0.748$, $P<0.000$) and statistically significant. Table 3 presents the Pearson correlation between the field VO_2 max and other field variables in an attempt to determine which is used to predict VO_2 max in the field through further analysis by linear regression.

According to the results, the variables total distance ($r = 0.768$, $P<0.000$), total time ($r = 0.770$, $P<0.000$) and final speed ($r = 0.737$, $P<0.000$) showed high and statistically significant correlation with field VO_2 max. This allowed for the development of an equation for the proposed test, using one of the variables.

Table 1. Descriptive Statistics and t-test of Physiological Variables (n = 24).

Variables	Mean	± SD	Minimum	Maximum	t	p
VO_2 max (F) (mL· kg^{-1}·min^{-1})	48.55	6. 56	37.62	60.64		
VO_2 max (T) (mL· kg^{-1}·min^{-1})	50.19	5.09	42.66	58.69	-1.850	0.077
HR max (F) (beats·min^{-1})	191.79	6.59	178	207		
HR max (T) (beats·min^{-1})	191.20	7.02	178	206	0.399	0.694
RER (F)	1.31	0.10	1.11	1.50		
RER (T)	1.30	0.09	1.14	1.47	0.539	0.595
V_E (F) (mL·min^{-1})	135.30	14.97	109.50	158.80		
V_E (T) (mL·min^{-1})	138.25	19.92	102.70	187.00	-0.842	0.408
Distance (F) (m)	1773.33	334.49	1180	2340		
Distance (T) (m)	2307.5	458.74	1490	3470	-8.177	0.000*
Total time (F) (min)	7. 72	1.36	5.30	10.11		
Total time (T) (min)	10.49	1.36	7.50	12.50	-15.475	0.000*
Speed max (F)(Km·h^{-1})	15.10	0.64	14	16		
Speed max (T) (Km·h^{-1})	18.04	1.42	15	20	-14.190	0.000*
Lactate Final (F) (mmol/l)	10.01	2. 14	6.66	14.19		
Lactate Final (T) (mmol/l)	9.95	2.68	5.67	2.68	0.100	0.921

*****P<0.05 - statistically significant differences (F –field test; T –treadmill test).

Table 2. Pearson's Correlation Between the Proposed Field Test and Treadmill Test.

Variables	Pearson (r)	P
VO_2 max Field x Treadmill	0.748 *	0.000
HR max Field x Treadmill	0.448 *	0.028
RER Field x Treadmill	0.257	0.226
V_E Field x Treadmill	0.550 *	0.005
Total Distance Field x Treadmill	0.717 *	0.000
Total Time Field x Treadmill	0.792 *	0.000
Final Speed Field x Treadmill	0.777 *	0.000
Final lactate Field x Treadmill	0.240	0.259

*P<0.05

Table 3. Pearson Correlation (r) Between the Field VO_2 max and other Field Variables.

Variables	Pearson (r)	p
VO_2 max field x HR_{max} field	0.180	0.382
VO_2 max field x R field	-0.500 *	0.013 *
VO_2 max field x MV field	0.315	0.134
VO_2 max field x Total distance field	0.768 *	0.000 *
VO_2 max field x Total Time field	0.770 *	0.000 *
VO_2 max field x Final Speed field	0.737 *	0.000 *
VO_2 max field x Final Lactate field	0.390	0.060

*P<0.05

The correlation analysis between the field test variables of total distance covered and maximum speed achieved showed the highest correlation levels when confronted with the VO_2 max measured directly in the field. This indicates that they can be used to predict the field VO_2 max, using a formula obtained through linear regression. These data are presented in Table 4.

Table 4. Simple Linear Regression Analysis (Field VO_2 max).

Variables	r	R^2	Adjusted R^2	SEE	P
Total distance	0.768	0.590	0.571	4.29	0.000*
Maximum Speed	0.737	0.544	0.523	4.53	0.000*

*P<0.05

Since the correlation found for the distance variable is considered high (r=0.768), this variable was used to predict field VO_2 max through the linear regression model in the proposed field test. There is also a high correlation (r = 0.737) for the variable maximum speed reached at the end of the test. Thus, from the regression analysis, two equations were established for the prediction of VO_2 max in the field test. The equations are:

Table 5. Established Equations for Predicting VO_2 max.

Prediction of VO_2 max using the distance covered in meters.
VO_2 max = (0.01507 x distance covered) + 21.829
Prediction of VO_2 max using the maximum speed in $km \cdot h^{-1}$.
VO_2 max = (7.536 x maximum speed) - 65.275

Using one of the equations above, it is possible to predict the VO_2 max for soccer players of the juvenile and junior categories. Thus, using the "proposed test," it is possible to determine the VO_2 max using the variables speed and distance, without the need for expensive equipment and highly skilled people to use them.

DISCUSSION

The major finding of the present study is that the "proposed test" can be used to estimate VO_2 max. The field test protocol may be preferred over the treadmill protocol, as the player is exposed to real game conditions since he performs the test in the field, wearing soccer cleats as opposed to the laboratory conditions. Moreover, the field test protocol is easily implemented and, therefore, useful in soccer training planning (19).

Comparing the results with another study (19,22), we note that experiments conducted in several countries had values of height and weight similar to this study. However, the anthropometric characteristics of teams from different countries and leagues showed a wide range of results, especially in body weight (14). Anthropometric studies of soccer players show that body weight and height are important to the performance of these athletes (14).

The values found in our study for the variables of distance and speed in the field were superior (1773.33 ± 334.49 m and 15.10± 0.64 $km \cdot h^{-1}$) to those of Castagna and colleagues (6), with distance values of 1.331 ± 291 m and speed values of 14.15 ± 0.65 $km \cdot h^{-1}$ for the Yo-Yo Endurance level 2. The differences found in our study for distance and speed of the field test and treadmill might have occurred because the initial speed of the field test (11.5 km/h) is greater than the initial speed of the treadmill test (8 $km \cdot h^{-1}$). Thus, the athlete remained a shorter time period in the field test.

The high level of blood lactate found in the athletes after the field test (10.0 ± 2.14 mmol/l) is also a criterion for the performance of VO_2 max and it shows that the use of anaerobic energy production during the maximal exercise effort (1).

The values for VO_2 max (48.55 $mL \cdot kg^{-1} \cdot min^{-1}$ and 50.19 $mL \cdot kg^{-1} \cdot min^{-1}$ for field test and treadmill, respectively, were lower than values reported in other studies (5,16,20,23). However, in the present study, the values for VO_2 max on a treadmill and VO_2 max in the field test did not differ statistically ($P<0.077$). So, it can be concluded that the proposed field test is statistically similar to the test performed on the treadmill.

The correlation for VO_2 max in the field and treadmill in this study is high ($r = 0.748$, $P<0.000$) and statistically significant. In other studies (10,16,17), the correlations between the field tests and the treadmill tests were inferior to ours. The results of the present study also agree with other researchers that support the idea that a portable telemetric ergospirometer is a reliable method for determining the aerobic power of a soccer athlete in the field (11,15,21,24). It seems that the "proposed field test" can effectively contribute in creating the best training plan and, therefore, lead to a higher level of sports performance in modern soccer.

The formulas found to indirectly determine the values of aerobic power show that the field test proposed in this study allows the subject to reach values of maximum aerobic power essentially the same as when determined by direct spirometry.

CONCLUSIONS

According to the results in this study, it is possible to establish two equations to estimate VO_2 max with a field test, one through the maximum speed reached and another by the distance covered. This finding is an excellent outcome, given the high cost of ergospirometry equipment, the time that is necessary to train the staff to use it, and the time-consuming ergospirometry tests in the laboratory. This field test can be adopted by coaches and applied in trained soccer athletes, helping to establish the maximum aerobic power of athletes in Juvenile and Junior categories with lower costs and time saved that can be used in training. Another important factor in the field test is the ecological validity of the test, since the athlete performs in conditions that are more similar to those of a real match (i.e., a field test in the grass and wearing soccer cleats). Finally, the proposed field test should be considered as an easy and useful tool for coaches and trainers for assessing the athlete's cardiorespiratory capacity before, during, and after a competitive season.

Address for correspondence: Daros LB, Midwestern State University of Paraná, Departament of Physical Education, St. Camargo Varela de Sá, 03, CEP: 85040-080, Guarapuava, Pr, Brazil, Phone +55 42 3629-8132, email: lbdaros@yahoo.com.br

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