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EVALUATION OF AEROBIC CAPACITY IN SOCCER PLAYERS: COMPARISON OF FIELD AND LABORATORY TESTS

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ABSTRACT: The purpose of this study was to evaluate the maximal oxygen uptake ($\dot{V}O_2$max) values in soccer players as assessed by field and laboratory tests. Fourteen amateur soccer players (mean age: 21.9 ± 2.5) performed 2 maximal field tests: the Yo-Yo intermittent recovery test level 1 (YIRT), and the 20-m multi-stage shuttle run test (MST), as well as 1 maximal test on the treadmill with the Bruce treadmill test (BTRT) protocol. A portable telemetric ergospirometry device was used during all the tests to determine $\dot{V}O_2$max. In addition, an estimated $\dot{V}O_2$max value was calculated for players after all the tests. At the end of the study, no significant differences were found between field and laboratory tests in terms of measured $\dot{V}O_2$max, HRmax and respiratory exchange ratio (RER) ($p>0.05$), whereas significant differences were found between field and laboratory tests in terms of estimated $\dot{V}O_2$max ($p<0.05$). In addition, there were no significant differences between measured $\dot{V}O_2$ and estimated $\dot{V}O_2$max in BTRT, whereas significant differences were found between measured $\dot{V}O_2$max and estimated $\dot{V}O_2$max in both YIRT and MST. Finally, while there was a strong relationship between $\dot{V}O_2$max and both MST and BTRT performance (distance covered), there was a moderate correlation between $\dot{V}O_2$max and YIRT performance. This study results suggest that it is necessary to use ergospirometry to accurately estimate aerobic capacity in soccer players. In addition, both MST and YIRT could be used to determine HRmax of players, and MST has a strong relationship with $\dot{V}O_2$max. Thus MST may also be a more favourable field-based assessment of soccer players' endurance performance.

KEY WORDS: soccer, $\dot{V}O_2$max, estimation, HRmax

INTRODUCTION

A number of laboratory and field tests have been developed to evaluate endurance performance in sports [10,12,19]. The maximum oxygen uptake test is exercise-mode specific, and is performed using sampling and analysis of expired air and measurement of ventilation [15]. Common types of exercise used in such tests are treadmill and cycle ergometry, in either case, the exercise testing protocols involve incremental increases in work load until exhaustion, and occur within a time frame of 8-12 minutes [15]. The major disadvantages of these methods are the requirement for expensive exercise ergometers, gas and ventilation analysers, and the need for medical attendance [15]. Therefore, they may not be ideal for team sports such as soccer, basketball [1]. Moreover, fitness tests that are performed in the field enhance the specificity of the evaluation which makes the validity of these tests increase [26]. For these reasons, there is keen interest among coaches in predictive field based tests such as the 20m multistage fitness test, Yo-Yo intermittent recovery test [1].

The most common field test for the estimation of $\dot{V}O_2$max is the 20m multistage fitness test (MST). Originally developed for adults [12] and modified later for children [13], it aims to simulate a continuous incremental exercise test to volitional exhaustion [7]. The MST is widely used by soccer players as a field test in order to examine endurance performance [26], and it has also been showed to have a strong correlation with ($r = 0.89$ to 0.92) [1,14,19]. On the other hand, in many sports such soccer, the exercise is intermittent and performance is related to the athletes' ability to repeated bouts of intense exercise [10]. The efficacy of soccer is associated with the amount of high-intensity movements (such as jump, change direction) performed during a game [2,4,9,17,22]. Therefore, it seems logical to evaluate the soccer player's ability to repeated bouts of intense exercise [10]. Thus the Yo-Yo tests were designed to examine The ability to perform bouts of repeated intense intermittent exercise and the ability to recover from intense exercise [26].

The difference between the MST and the Yo-Yo tests is the intermittent exercise pattern used in the Yo-Yo tests [10]. In both of the Yo-Yo tests, a recovery period is incorporated after each pair of 20-m shuttle runs [26]. Performance during both field tests has been vali-

dated against measured $\dot{V}O_2$max obtained during treadmill running in soccer players [1]. Aziz et al. [1] compared the performances obtained in the MST and the Yo-Yo intermittent endurance test (YIET) with the measured $\dot{V}O_2$max obtained in both field tests as well as that in the traditional test of running to exhaustion on a treadmill (TRT) and they found that measured $\dot{V}O_2$max of subjects obtained in YIET and MST were similar. They also found that in comparison with the MST, YIET may also be a more effective field-based assessment of soccer player's endurance performance. However, no previous study has compared the YIRT with the MST, nor have any studies examined the estimated $\dot{V}O_2$max values of these tests. Therefore, the purpose of this study was to compare estimated $\dot{V}O_2$max for the MST, YIRT and the BTRT with measured $\dot{V}O_2$max using an oxygen analyser in these three tests.

MATERIALS AND METHODS

Subjects. Fourteen soccer players voluntarily participated in the study. The players' physical characteristics were (mean±sd): age 21.9 ± 2.5 years, height 176.1 ± 8.5 cm and body mass 72.2 ± 6.8 kg. Players were informed of the tests' protocols and procedures, but to ensure that players devoted equal effort to each trial, the aim of the study was not disclosed. All players were recruited from amateur teams, and had been playing competitively for at least five years. They were familiarized with the tests' protocols and had undergone the MST, YIRT and BTRT at least once prior to the study. The players provided written informed consent for the study, which was approved by the Pamukkale University ethics committee.

Procedures

The three test trials were conducted as separate sessions interspersed between 3-4 days for each player. The YIRT, MST and BTRT were conducted as randomized balance trials among the 14 players. All test trials for each player were completed within two weeks. All trial times for each player were standardized within 1 hour and conducted between the times of 09:30 and 11:30. The YIRT, MST and BTRT trials were conducted at the same indoor location. Players ran alone, were instructed to exert maximal effort and were verbally encouraged to run for as long as possible. They wore the same running shoes/trainers for all their test trials. Standardized warm-up for the MST and YIRT trials consisted of 3 minutes of running the 20 m distance back and forth at a set pace (i.e. 8.0 km·h^{-1}) with the help of "beep" sounds emitted from a compact disc player; for the BTRT trials, they consisted of 3 minutes of running on treadmill at 8 km·h^{-1}. This was followed by 5 minutes of self-stretching, focusing on the lower limb muscles. This procedure was the same with Aziz et al. [1]. All subjects performed 2 maximal field tests: the Yo-Yo Recovery Test level 1 (YIRT), and the 20-m multi-stage shuttle run test (MST), as well as 1 maximal exercise test on the treadmill with the continuous Bruce treadmill test (BTRT) protocol. During the test, expired gases were analysed using a breath-by-breath automated gas-analysis system (Oxycon Mobile; Viasys Healthcare, Hoechberg, Germany). The flow, volume, and gas analyser were calibrated before each test according to the manufacturer's instructions. Achievement of $\dot{V}O_2$max was considered as the attainment of at least two of the following criteria: 1) a plateau in $\dot{V}O_2$max despite increasing speed, 2) a respiratory exchange ratio above 1.10, and 3) HR ± 10 beats·min^{-1} of age-predicted maximal HR (220 - age). In addition, an estimated $\dot{V}O_2$max value was calculated for players after all the tests. HR measurements data were stored using HR monitors (Polar Electro OY, Kempele, Finland) throughout the tests. The stored data were transferred to a computer and filtered by Polar Precision Performance Software™ (PPP4, Finland). The highest HR measurement was recorded as HRmax. The temperature and relative humidity at the test site were consistent throughout the study, ranging between 22.4-24.6 ºC and 62.3-66.7 % respectively.

20-m multi-stage shuttle run test (MST)

The 20-m MST required subjects to run back and forth between 2 cones set 20 m apart. Subjects started running at an initial speed of 8.5 km·h^{-1}, which increased by 0.5 km·h^{-1} every minute. The player was warned once if he did not reach the end line in time. The test was terminated when he a) could not follow the set pace of the "beeps" for two successive shuttles, and/or b) stopped voluntarily. Typically the scores in the MST are expressed as levels and shuttles, but these values are discontinuous and cannot be used in statistical analysis. The total distance covered (i.e. 20 m x the number of completed shuttles) was therefore reported as the player's performance measure in the MST and used in the statistical analysis [1]. The $\dot{V}O_2$max value of the subject was estimated from the MST test using Formula 1.

MST estimated $\dot{V}O_2$max = –24.4 + 6.0 x (maximal shuttle run speed) [13]

(Formula 1)

The Yo-Yo intermittent recovery test (YIRT)

The YIRT consists of repeated 2 x 20 m runs back and forth between the starting, turning, and finishing line at a progressively increased speed controlled by audio beeps from a tape recorder. Between each running bout, the subjects had a 10-s active rest period, consisting of 2 x 5 m of jogging [3]. When the subjects twice had failed to reach the finishing line in time, the distance covered was recorded as the test result. The test may be performed at two different levels at different speed profiles (level 1 and 2). In the present study, we used YIRT level 1, which consists of 4 running bouts at 10–13 km·h^{-1} (0–160 m) and another 7 runs at 13.5–14 km·h^{-1} (160–440 m), after which it continues with stepwise 0.5 km·h^{-1} speed increments after every 8 running bouts (i.e., after 760 m, 1080 m, 1400 m, 1720 m, etc.) until exhaustion [10]. The test was performed indoor on running lanes, marked by cones, having a width of 2 m and a length of 20 m. Another cone placed 5 m behind the finishing line marked the running distance during the active recovery period. The $\dot{V}O_2$max value of the subject was estimated from the YIRT test using Formula 2.

YIRT estimated $\dot{V}O_2$max=24.8 + (0.014 x maximum running distance in Yo-Yo test (m))
(Formula 2)

Bruce treadmill test (BTRT)

Treadmill exercise testing was performed using the Bruce treadmill protocol to voluntary exhaustion on a motorized treadmill (Cosmed, Gambettola, Italy). All tests were performed under standardized conditions in a stable laboratory environment. The *BTRT* protocol consisted of seven 3-minute stages: (1) 2.74 km·h^{-1} at a slope of 10%, (2) 4.02 km·h^{-1} at a slope of 12%, (3) 5.47 km·h^{-1} at a slope of 14%, (4) 6.76 km·h^{-1} at a slope of 16%, (5) 8.05 km·h^{-1} at a slope of 18%, (6) 8.85 km·h^{-1} at a slope of 20%, and (7) 9.65 km·h^{-1} at a slope of 22%. The test continued until the subject could no longer continue. The $\dot{V}O_2$max value of the subject was estimated from the *BTRT* test using Formula 3.

BTRT estimated $\dot{V}O_2$max = 14.76 - (1.379 x T) + (0.451 x T^2) - (0.012 x T^3)
(T = Exhaustion time) (Formula 3)

Statistical analyses

The data are reported as means and standard deviations. Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk test. A one-way repeated-measures analysis of variance was performed on physiological responses in the MST, YIRT and BTRT. A Bonferroni post hoc test was applied to make a pairwise comparison between MST, YIRT and BTRT tests. The Pearson product moment correlation coefficient (r) was used to determine the relationship between the players' performance and measured $\dot{V}O_2$max for the three tests. The pair t test was used to evaluate differences in the measured $\dot{V}O_2$max values and estimated $\dot{V}O_2$max values of tests. The level of statistical significance was set at $p < 0.05$.

RESULTS

Table 1 shows the physiological responses obtained during the MST, YIRT and BTRT for the 14 players. No significant differences were found between field and laboratory tests in terms of measured $\dot{V}O_2$max, HRmax and RER ($p>0.05$), whereas YIRT estimated $\dot{V}O_2$max values significantly different from MST and BTRT estimated $\dot{V}O_2$max values ($p<0.05$). There were no significant differences between measured $\dot{V}O_2$max and estimated $\dot{V}O_2$max in BTRT, whereas significant differences were found between measured $\dot{V}O_2$max and estimated $\dot{V}O_2$max in both YIRT and MST ($p<0.05$).

Table 2 shows the correlations between the performances (distance covered) in the three tests and the measured $\dot{V}O_2$max obtained for the 14 players. There were moderate correlations between performance in the YIRT (1222.9±287.0 m) and the measured $\dot{V}O_2$max obtained in all the three tests. In contrast, there were strong significant correlations between performance in the MST (1940±244.3m) and BTRT (1215.9±157.8 m) and measured $\dot{V}O_2$max in all the three tests.

TABLE 1. COMPARISON OF THE PHYSIOLOGICAL RESPONSES IN THE BTRT, MST AND YIRT IN SOCCER PLAYERS

	BTRT	MST	YIRT
Measured $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	49.71 ± 3.60	49.00 ± 4.06#	49.04 ± 4.58 ¥
Estimated $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	50.56 ± 4.93 *	52.31 ± 3.04 *	41.92 ± 4.02
HRmax (bpm)	194.57 ± 9.17	194.64 ± 10.09	196.64 ± 9.53
RER	1.15 ± 0.04	1.15 ± 0.03	1.13 ± 0.03

Note: *significantly different from the YIRT, $p < 0.05$; # significantly different from the estimated MST, $p < 0.05$; ¥ significantly different from the estimated YIRT, $p < 0.05$; $\dot{V}O_2$max = Maximal oxygen uptake; RER = Respiratory exchange ratio; HRmax = Maximal heart rate. MST= 20-m multi-stage shuttle run test, YIRT= Yo-Yo Intermittent Recovery Test level 1, BTRT= Bruce treadmill test

TABLE 2. CORRELATION OF THE MEASURED VO2MAX AND DISTANCE IN THE MST, YIRT AND BTRT IN SOCCER PLAYERS

	BTRT $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	MST $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	YIRT $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})
BTRT Distance (m)	0.86*	0.84*	0.85*
MST Distance (m)	0.84*	0.85*	0.86*
YIRT Distance (m)	0.55*	0.61*	0.54*

Note: MST= 20-m multi-stage shuttle run test, YIRT= Yo-Yo Intermittent Recovery Test level 1, BTRT= Bruce treadmill test. * $p < 0.05$

DISCUSSION

The major finding of this study is that there were no significant differences between the 20-m multi-stage shuttle run test (MST), Yo-Yo intermittent recovery test level 1 (YIRT), and the Bruce treadmill test (BTRT) protocol in terms of the measured $\dot{V}O_2$max values. This result is supported by Aziz et al. [1], who found similar maximal exercise responses to the MST, Yo-Yo intermittent endurance test and $\dot{V}O_2$max test on a treadmill (TRT) in eight football players; Aziz et al. reported that the magnitude of the mean differences in measure $\dot{V}O_2$max was small, and within the typical daily variability of <5% or ± 2 ml·kg^{-1}·min^{-1}. Determining $\dot{V}O_2$max in the TRT as the 'gold standard' [8,20], both the Yo-Yo and MST were deemed valid field-based tests of $\dot{V}O_2$max in soccer players [1].

$\dot{V}O_2$max is considered as the gold standard for measurement of aerobic fitness [25]. The measurement of $\dot{V}O_2$max demands sophisticated instrumentation, laboratory time, and trained personnel, and it may not be appropriate for some applications [23]. For these reasons, there is interest in predictive tests that can serve as convenient alternatives to $\dot{V}O_2$max measurement [1]. This investigation found that while there were significant differences between estimated $\dot{V}O_2$max values for the MST, YIRT and measured $\dot{V}O_2$max values for the two tests, there were no significant differences between the measured values and estimated values for the BTRT. The standard deviation from the regression line was ± 3.5 ml·kg^{-1}·min^{-1}. Stickland et al. [23] compared the two equations of MST with measured $\dot{V}O_2$max and they found that both regression Equation 1 [13] and Equation 2 [14] systematically underestimated $\dot{V}O_2$max for both females and males. Such methodological concerns are also supported by evidence that indicates a lack of consistency in correlations of test results with $\dot{V}O_2$max. Sproule et al. [21] observed that the estimated $\dot{V}O_2$max from performance in the MST test was lower than that obtained in measured $\dot{V}O_2$max on the treadmill in 75% of twenty participants. Similar findings were reported by St Clair-Gibson et al. [24] $\dot{V}O_2$max was underestimated in squash players and runners, with average values of 61 ml·kg^{-1}·min^{-1} on the MST and 66.5 ml·kg^{-1}·min^{-1} on the treadmill. The underestimations may be greater for individuals with higher $\dot{V}O_2$max and be partly dependent on the specific sport. In our study, the results were found to be within this range. No previous study has compared estimated values for the BTRT, YIRT and measured values of these tests.

One of the important findings of this study relates to the comparison of HRmax for the MST, YIRT and BTRT. HR monitoring is one of the most popular indirect methods to estimate energy expenditure as it is a practical and low-cost method that brings little inconvenience to the subject [18]. We found that there were no significant differences between HRmax values for the three tests. Stickland et al. [23] reported similar results to our study and they determined no differences between HRmax from the YIRT test and that from the MST. Additionally, Metaxas et al. [16] determined HRmax using 2 maximal field tests: the Yo-Yo endurance test (continuous) and the Yo-Yo endurance test (intermittent) as well as 2 maximal exercise tests on the treadmill with continuous and intermittent protocols and they found no significant differences in HRmax values between the four tests. According to our results, YIRT, MST and BTRT tests could be used interchangeably to determine HRmax.

We found strong relationships between measured $\dot{V}O_2$max and both MST performance (distance covered) and BTRT performance. The present study results support observations obtained by other studies. For example, Leger and Gadaoury [14] found a strong relation between the MST performance and measured $\dot{V}O_2$max and it was concluded that MST is a valid test to estimate $\dot{V}O_2$max in adults. Ramsbottom et al. [19] found a correlation of 0.92 between $\dot{V}O_2$max and MST performance. Aziz et al. [1] reported that there were strong and moderate relationships between the MST and measured $\dot{V}O_2$max values and they concluded that the MST may be more suited for the assessment of endurance performance that is performed continuously. The present study found a moderate association between the YIRT and measured $\dot{V}O_2$max in the three tests. A similar response was obtained when the YIRT2 test was evaluated by Krustrup et al. [11] and a correlation of 0.56 between YIRT2 and $\dot{V}O_2$max was reported. Castagna et al. [6] found no correlation between $\dot{V}O_2$max values and the BTRT and YIRT performance. Aziz et al. [1] found a weak relationship between $\dot{V}O_2$max and Yo-Yo intermittent endurance test performance. In contrast, Thomas et al. [27] described strong correlations for YIRT performance and measured $\dot{V}O_2$max ($r = 0.87$). Krustrup et al. [10] found YIRT performance to also correlate strongly with $\dot{V}O_2$max ($r = 0.71$). However, the relationship between the YIRT and $\dot{V}O_2$max represented a scattered Picture [5]. The correlation between the results of this study and those of previous studies suggest that the MST provides a valid estimate of $\dot{V}O_2$max and in practice coaches should be more concerned with the absolute performance measure attained in the MST test rather than the players' $\dot{V}O_2$max and Yo-Yo test results, but it should be recognized that differences between measured and MST estimated $\dot{V}O_2$max values are common [27].

CONCLUSIONS

The results of this study suggest that it is necessary to use ergospirometry to accurately estimate aerobic capacity in soccer players. In addition, both MST and YIRT could be used to determine HRmax of players, and MST has a strong relationship with $\dot{V}O_2$max. Thus MST may also be a more favourable field-based assessment of soccer player's endurance performance. On the other hand, it seems that YIRT may be more suitable to characterize soccer players' intermittent endurance performance.

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