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A comparison of three different shuttle run tests for the prediction of Vo^2 max

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Abstract
The purpose of the present research is studying the relations and differences between VO2max values and heart beat frequencies calculated with three different shuttle run tests used to determine the aerobic and anaerobic capacities of soccer players. Eleven amateur trained male soccer players (age = 23.18 ± 1.83 years, sport age = 11.82 ± 1.99 years) voluntarily participated in the present research. 20m Shuttle Run Test (20mSRT), Yo-Yo Intermittent Recovery Test level 1 (YYIRT1) and level 2 (YYIRT2) running tests, which are frequently used in VO2max. calculations, were performed by players on different days. Significant relations were found between heart rate frequencies and VO2max. values calculated after 20m SRT and YYIRT1, and YYIRT1 and YYIRT2 (respectively; r = 0,628, p<0,05: r = 0,921, p<0,01). No significant relations were found between 20mSRT and YYIRT2 (p>0,05). There was no significant difference between heart rate averages after 20m SRT and YYIRT1 (p> 0.05). There was a significant difference between the VO2max averages calculated according to 20m SRT, YYIRT1 and YYIRT2 levels (p<0.01). Consequently, we can claim that occurred a similar workload on athlete's because of the similarity between the athletes' heart rate averages after 20m SRT and YYIRT1. But there was no such similarity between VO2max values calculated from both test scores of the players. According to these findings, it is revealed that different energy sources are used in the performance of both tests. Higher heart rate averages and estimated VO2max values for YYIRT2's performance showed that the energy metabolism used was different for the other two tests and the workload intensity on the athlete was higher.

Keywords: Soccer, VO_2max. heart rate, 20mSRT, YYIRT1, YYIRT2

1. Introduction

Outputs of time-motion analysis used in the detection of all physical activities that a player exhibits during the match [2, 4, 27, 36] and automatic soccer video analysis [26] reveal that the players exhibit high level of physical activity [14, 20, 29]. In soccer games involving intermittent exercises such as low-to-moderate and high-intensity running, sprints, turns and jumps, players need to have physiologically high aerobic capacity and rapid anaerobic energy conversion capability [5, 20].

In Elite soccer games a player covers a total distance of about 10-12 km. Although the proportion of high intensity running (about 30%) is lower than that of walking and low intensity running, performing high intensity running and activities at short intervals and frequently is physically and physiologically difficult for the players [10, 11, 28, 33]. A player must have a high oxygen consumption capacity (VO2max> 55ml.kg^{-1}.min^{-1}) while performing at a high heart rate (HRmax 80-90%) during the match. Therefore, this information should be used effectively in order to prepare the players for the required performance level in a game. Accordingly, some test protocols have been developed to determine the readiness of the players in terms of their physical and physiological characteristics [2, 3, 7, 8, 19, 21, 34, 42, 46]. It is reported that 20-meter Shuttle Run Test can be used to determine maximal aerobic power and to predict maximal oxygen uptake (VO2max) as a reliable test (r = 0,84; SEE = 5.4 ml.kg^{-1}.min^{-1}) besides field tests [23]. Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) and Yo-Yo Intermittent Recovery Test Level 2 (YYIRT2), which are intermittent running tests, are frequently used to measure high intensity aerobic work and anaerobic energy production capacity [6, 19, 21, 31].

It is reported that intermittent tests, which are considered as a simulation of the intermittent movements of the players at different densities particularly in a soccer match, are effective in determining the physical and physiological performances of the players, and factors such as position differences, being regular players, being in the higher ranked teams and pre-season, during and end of season performances [6, 44] present results related with these two intermittent test performances [30]. The physiological responses of the athletes indicate that YYIRT2 has more pronounced anaerobic components than YYIRT1 [6, 21]. Previous studies suggest the use of 20mSRT in determining aerobic capacity status of athletes for continuous running performance, YYIRT1 for intermittent recovery running and YYIRT2 for anaerobic capacity.

However, these tests seem to be misused due to lack of information. For example, YYIRT2 is administered at the beginning of the season to determine the endurance status of the athletes or YYIRT1 is used to determine anaerobic endurance for elite trained athletes. These misapplications result in mistakes in the evaluation of athletes' performance. It is therefore necessary to emphasize the importance of using these three increasing speed run tests in at the right time. The purpose of the present research is to study the changes in and the relationships between the calculated performance scores of the three different (20mSRT, YYIRT1 and YYIRT2) tests applied to amateur footballers, calculated predict maximal oxygen capacities and heart rate values.

2. Materials and Methods

2.1 Experimental Group

11 male amateur trained soccer players (age = 23.18 ± 1.83 years, sport age = 11.82 ± 1.99 years) voluntarily participated in the present research. Soccer players practice regularly during the week and compete in the local super amateur league where official matches are played on weekends. The measurements were taken during the season. In accordance with the Helsinki Convention, the scientific ethics committee permission was granted and all the athletes signed the acceptance form.

2.2 20 Metre Shuttle Run Test (20msrt)

It is a test in which the athletes run on a straight line in a round-trip (shuttle) pattern on the field marked at 20 meters intervals. The subjects run at a speed of 8.5 km / h-1 at the beginning and increase their pace at a speed of 0.5 km / h-1 in each minute. The running pace is given with an audio device that produces an audible signal at a volume, which athletes can hear. Each completed shuttle and level is recorded until the test is terminated [25].

2.3 Yo-Yo Intermittent Recovery Tests (Yyirt)

The test area is marked as 20 meters running and 5 meters recovery area. In the marked area, turnaround (shuttle) is run as 2 * 20 meters, followed by a 2 * 5 meter walk in the recovery area or active recovery with 10 seconds running at low speed. Subjects have to comply with the audio device, which produces an audible signal and provides increasing acceleration. The Yo-Yo level 1 test (YYIRT1) starts at 10 kmh-1 speed, while the Yo-Yo level 2 test (YYIRT2) starts at 13 kmh-1 speed [6]. The subject should reach to the return and arrival lines to match the signal tone. If they cannot reach the arrival line twice or in case of exhaustion, the test is terminated, the level and distance of the covered is recorded.

2.4 Heart Beat

On each test day, subjects were instructed to wait sitting for 5 minutes without doing performing any physical activity, and the lowest value was recorded as resting heart rate. At the beginning of each of the three tests, and after the tests for 3 minutes, the recovery heart rate was measured with a heart rate monitor (Polar RS800CX, Electro Oy, Kempele, Finland) and recorded at 5-second intervals. The maximal heart rate values of the subjects were recorded during the YYIRT2 application.

Predict maximal oxygen capacity (VO2max). VO2max calculations were made using the following equations according to the three test values of the subjects.

VO2max equation calculated based on 20mSRT values.
VO2 max (ml.kg^{-1}.min^{-1}.) = – 32,678+ (6,592 x Max. Speed (kmh) (25).

VO2max equation calculated based on YYIRT1 values.
VO2max (ml.kg^{-1}.min^{-1}.) = YYIRT1 distance (m) × 0.0084 + 36.4 (6).

VO2max equation calculated based on YYIRT2 values.
VO_2max (ml.kg^{-1}.min^{-1}.) = YYIRT2 distance × 0.0136 + 45.3 (6).

Some studies have provided various equations exploring the level of reliability for 20mSRT performance and VO2max estimation with direct measurements. These studies were conducted on children [24, 45], adolescents [24, 37], and young adults [22, 24, 35, 40]. This test was reported to have lower validity in adults older than 30 [24, 25]. The results of the previous studies generally showed strong correlations between 20mSRT and VO2max made by direct measuring method and retest values.

2.5 Experimental Design

Subjects applied three tests at intervals of one day. Before takings the tests on the day of tests, the athletes did not participate in an exhausting physical activity. Resting heart rates of all participants were recorded. The subjects warmed up enough before tests. The heart rate values of the athletes were recorded at the beginning of the test and during the test. Predict VO2max values were calculated using test scores and running distances.

2.6 Analysis of Data

The average of data is presented (± sd). The heart rate averages, test distances, and estimated VO2max values of the subjects for three tests were tested for correlation (Pearson correlation) and difference analysis (paired sample t-test) in the statistical package program on the computer. The significance level of the statistics was taken at the level of 0.05. To determine the significance of the change between VO2max and heart rate data obtained from the tests, the effect size (Cohen's d) was classified to be large ($d \geq 0,8$), medium ($0.2 < d < 0,8$) or small ($d \leq 0,2$) [9].

3. Discussion

According to the findings of the present research, the footballers reached higher YYIRT2 heart rate values close to the maximal heart rate (94.6%). 20mSRT and YYIRT1 heartbeats are close to each other and that the subjects completed the tests at 87% of maximal heart rate. The predict VO2max levels present different values in three tests. The highest VO2max value was also found at YYIRT2.

The average 20mSRT running distance obtained in the present research was 1900,00 ± 185,69 m, the running speed was 12,86 ± 0,32 km., the heart rate was 173,18 ± 7,36 bpm, the predict VO2max average was 52, 12 ± 2,13 ml.kg-1.min-1.

Tonnessen *et al*. [44] reported the average VO2max value of 1545 male footballers in different categories in the Norwegian league as 62-64 ml.kg-1.min-1 by direct measurement with gas analysis method. This value was found to be significantly higher than the value calculated with 20mSRT result. Higino *et al*. [16] reported the VO2max average of 27 young soccer players (age = 16.77 ± 0.75) as 59.21±5.88 ml.kg^{-1}.min^{-1} as results of direct gas analysis in lab and predict VO2max average as 50.67±3.58 ml.kg^{-1}.min^{-1} as results of 20mSRT. In some previous studies, VO2max values were reported as about 58.5 ml · kg-1 · min-1 [34] for professional footballers, about 59 ml · kg-1 · min -1 for elite professional footballers, and 56 ml · kg-1 · min -1 for elite soccer players [13].

The VO2max estimation method with 20mSRT performance, which does not give a definite result like laboratory tests where VO2max is determined directly by measuring the respiratory air, reveals different findings in previous studies. In addition to the studies, which reported that direct measurement and 20mSRT performance were significantly correlated with estimated VO2max values (r = ~ 0.90) [32, 35], and those reported no significant differences (1.12), there are also studies, which reported that the predict VO2max value was lower than the direct measurement values [15, 38, 39]. Lamb and Rogers [22] indicate that estimation formulas developed for VO2max calculation using 20mSRT are affected by factors such as sample size, heterogeneity, and other dependent variables used in regression models.

Despite all these different results, 20mSRT is commonly used in the prediction of VO2max in football. However, it has been argued whether it is a very sensitive method in organizing training practices or determining player characteristics in football [42].

Thomas *et al*. [43] found a significant relationship (r = 0.80) between the performance of YYIRT1 and the estimated 20mSRT and estimated VO2max values in amateur athletes and sub-elite athletes, which is in agreement with previous studies and also shows that the aerobic energy system is important in YYIRT1 performance [19, 41]. However, no significant relationship was observed in YYIRT2 performance. Since YYIRT2 is applied at high speed and requires anaerobic energy metabolism ability, it may not be suitable for not well-trained or non-elite athletes. In the same study, it was reported that there was a high correlation (r = 0.80) between YYIRT2 values and 20mSRT and estimated VO2max values in elite athletes, which is in agreement with this information.

Mohr and Krustrup, [30] reported in their study conducted on 219 sub-elite professional male soccer players (age = 25,8 ± 4,1) that YYIRT1 performance data showed significant variations according by the periods of season. The heart rate average and HBmax ratio (176 ± 11 bpm-1; 90,9 ± 4,2% HBmax) obtained in the pre-season test (distance = 1838 ± 362 m.) were found to be significantly higher than the values measured at the beginning of the season, during the season and at the end of the season (respectively; 168 ± 10; 166 ± 9; 169 ± 10 bpm-1 and 87,0 ± 3,9; 85,9 ± 4,1; 87,0 ± 3.7%) (p<0,001). The effect size of heart rate change in YYIRT1 performance was found to be "large" from pre-season on the beginning of the season, and "small" on the beginning of the season and the end of the season. The mean distance obtained before the season in YYIRT2 performance (847 ± 227m) increased significantly in the tests conducted at the beginning of the season (975 ± 205 m) and during the season (1034 ± 211 m) (p<0,01) was reported to have fallen at the end of the season (978 ± 180 m) compared to the results obtained during the season. 51% of the players reached peak YYIRT2 performance
(1068 ± 193 m) during the season, while 7% did pre-season, 19% at the beginning and 23% at the end of the season.

The YYIRT2 performance of footballers develops with pre-season trainings [6, 21] and high-intensity trainings done for a certain period [17, 30].

Additionally, it was reported that there was a high correlation (r = 0.70) between both Yo-Yo test results obtained before the season and a moderate correlation between both Yo-Yo test results obtained in all season periods. Although these two tests used to determine the physical fitness of the athletes have some similarities, the YYIRT2 performance cannot be predicted from the results of YYIRT1. Previous studies have reported that the performance of yo-yo tests differed between the two tests in terms of physiological responses such as decreased muscle creatine-phosphate, muscle lactate accumulation. Common aerobic capacity among athletes is determined with 20mSRT, while intense aerobic and low density anaerobic capacity are determined with YYIRT1 and dense anaerobic capacity is with YYIRT2 [6, 18, 21].

3.1 Tables and Figures

Mean (± sd) age and sport age of the 11 male amateur trained soccer players participating in the study were calculated as (23.18 ± 1.83 years, 11.82 ± 1.99 years respectively). The highest heart rate athletes reached during the YYIRT2 run was 188, 82 ± 6,19 beats per minute (bpm). Table 1 shows the heart rate averages of the athletes recorded on test days at rest, at the beginning and end of the running tests, and after 3 minutes rest period. Additionally, the maximal heart rate percentages reached by the athletes in the running tests were found as HR20mSRT% = 87,04 ± 5,85%, HRYYIRT1% = 86,87 ± 3,17% and HRYYIRT2% = 94,63 ± 2,03%, and the maximal running speeds they reached were; 20 mSRT = 12,86 ± 0,32, YYIRT1 = 15,73 ± 0,41 and YYIRT2 = 17,73 ± 0,26 km / h-1 (Table 2).

Table 1: Pre-post test, resting, maximal and recovery heart rate data (mean±sd)

Tests (n=11)	HRrest (bpm)		HRstart (bpm)		HRfinish (bpm)		HRrecov. (bpm)		HRmax. %	
	Mean (min-max)	Sd.	Mean (min-max)	Sd.	Mean (min-max)	Sd.	Mean (min-max)	Sd.	Mean (min-max)	Sd.
20mSRT	69,73 (64-82)	5,46	82,00 (74-93)	5,93	173,18 (160-182)	7,36	95,73 (85-106)	7,62	87,04 (74-97)	5,85
YYIRT1	69,09 (61-76)	4,74	83,00 (70-105)	9,39	173,18 (163-184)	7,00	96,45 (87-115)	8,38	86,87 (82-90)	3,17
YYIRT2	69,64 (62-75)	4,80	82,64 (72-97)	6,68	182,45 (172-192)	6,41	100,09 (88-112)	9,01	94,63 (90-98)	2,03

HR= Hearth Rate, bpm=beats per minute, rest= resting, strart= beginning of running tests, finish= end of running tests, recov.= end of the 3 min.recovery period, HRmax%= percent of maximal heart rate, 20mSRT= 20 meter Shuttle Run Test, YYIRT1= Yo-Yo Intermittent Recovery Test Level 1, YYIRT2= Yo-Yo Intermittent Recovery Test Level 2.

Table 2: Running Speed, Distance Covered and Predicted VO_2max. Data (mean±sd)

Tests (n=11)	Speed (km.sa^{-1})		RD (m)		VO2max (ml.kg^{-1}.dk^{-1}.)	
	Mean (min-max)	Sd.	Mean (min-max)	Sd.	Mean (min-max)	Sd.
20mSRT	12,86 (12,5-13,5)	0,32	1900,00 (1680-2260)	185,69	52,12 (49,72-56,31)	2,13
YYIRT1	15,73 (15-16,5)	0,41	1320,00 (1080-1600)	161,00	47,49 (45,47-49,84)	1,35
YYIRT2	17,73 (17,5-18)	0,26	778,18 640-1000	96,94	55,88 (54,00-58,90)	1,32

RD= running distance, VO2max= predict maximal oxygen uptake, 20mSRT= 20 meter Shuttle Run Test, YYIRT1= Yo-Yo Intermittent Recovery Test Level 1, YYIRT2= Yo-Yo Intermittent Recovery Test Level 2.

There was a significant difference between the distances covered in all three tests (*p*>0, 01). There are significant strong correlations between 20mSRT of longest running distance (1900.00 ± 185.69 m.) and YYIRT1 (1320.00 ± 161.00 m.) (r = 0.82, *p*<0.01) and YYIRT2 (778.18 ± 96.94 m) (r = 0, 78; *p*<0, 01). There is no significant relationship between YYIRT1 and YYIRT2 running distances (*p*>0, 05) Fig 1.

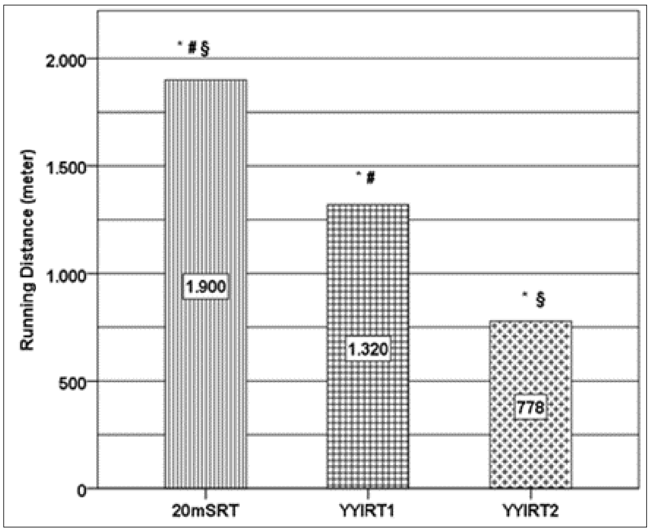

Fig 1: The total distance values covered in the tests.

* The difference between running distances of all tests is significant (*p*<0.01). There was a significant correlation between # 20mSRT and YYIRT1 and between §20mSRT and YYIRT2 (*p*<0.01).

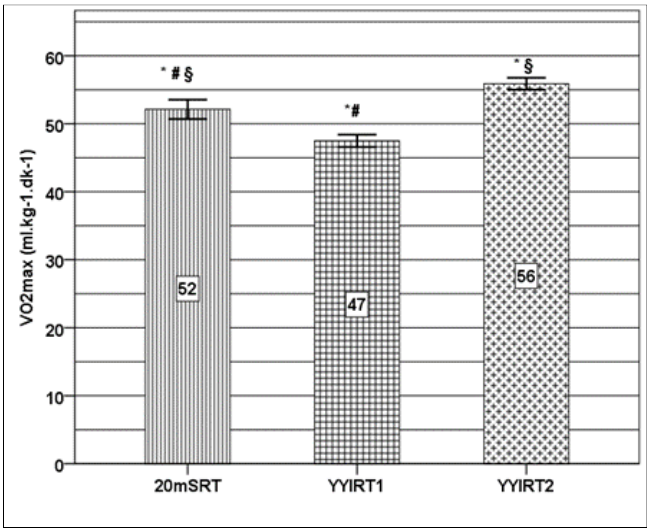

Fig 2: The predict VO2max values based on all three test performances.

*The difference between the VO2max averages of all tests is significant (*p*<0.01). There are significant relations between YYIRT1 and # 20mSRT; and YYIRT2 VO2max and § 20mSRT. (*p*<0.01).

The calculated predict maximal oxygen consumption capacity (VO2max) averages are 20mSRT = 52.12 + 2.13, YYIRT1 = 47.49 + 1.35, YYIRT2 = 55.88 + 1.32 (ml.kg-1.min-1). A significant difference was found between the three tests in the predict VO2max values calculated according to the running distance of the athletes in the tests (*p*<0, 01). There was a significant positive correlation between 20MSRT and YYIRT1 (r = 0.81) and YYIRT2 (r = 0.79) (*p*<0.01). There is no significant relationship between YYIRT1 and YYIRT2 (*p*>0, 05). The size of the effect was also found to be large between all three tests (d> 0.80).

Table 3: Predict VO2max and correlation and difference analyses between the end of the tests and the recovery HB values

Variable (Pairs)		r	p	t	p	ES
VO_2max	20mSRT YYIRT1	0,81**	0,00	11,70**	0,00	Large (2,60)
	20mSRT YYIRT2	0,79**	0,00	-9,18**	0,00	Large (2,12)
	YYIRT1 YYIRT2	0,47	0,14	-20,28**	0,00	Large (6,28)
HR end	20mSRT YYIRT1	0,63*	0,04	0,00	1,00	Similar
	20mSRT YYIRT2	0,56	0,08	-4,71**	0,00	Large (1,34)
	YYIRT1 YYIRT2	0,92**	0,00	-11,29**	0,00	Large (1,38)

**p*<0, 05 and ***p*<0,01 significance level

At the end of the tests at exhaustion level, in terms of the mean level of heart rates of subjects there was a medium level significant correlation between 20msRT and YYIRT1 (r = 0.63; p = 0.04) and a positive strong correlation between YYIRT1 and YYIRT2 (r = 0.92) <0.01). There was no significant relationship between 20mSRT and YYIRT2 (*p*>0.05). The size of the effect between 20mSRT and YYIRT1 (d = 2, 60) and YYIRT2 (d = 2.12) and between 20mSRT and YYIRT2 (d = 6, 28) is large (d> 0,80). There was no statistically significant difference between the recorded recovery heart rate averages of the subjects at the end of 3 min after the end of each test (*p*>0.05).

4. Conclusion

In conclusion, we can claim that the two tests constitute a similar workload on the athletes due to the similarity of athletes' post 20msRT and YYTRT1 heart rate averages. However, there is no such similarity for predict VO2max values. Therefore, it can be claimed that the use of energy sources for both tests is different. Both HR frequency and

VO2max values obtained with YYIRT2 are higher than the other two tests, which reveals the difference in the used energy metabolisms and the intensity of workload on the athlete. In accordance with this information, the coaches should use 20mSRT to identify and monitor the current aerobic capacities of players, use intermittent activity training at the beginning of the season and the period that follows, and use Yo-Yo Interval Recovery Tests during the process of developing anaerobic energy metabolism.

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