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The use of Yo-Yo intermittent recovery test level 1 for the estimation of maximal oxygen uptake in youth elite soccer players

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Abstract

Introduction. Researchers have proposed some equations for the estimation of VO_2max in adults with the use of the total distance or the maximum velocity of the Yo-Yo test. However, the use of these equations for estimating the VO_2max in children may include mistakes. Their physiological adaptations to incremental exercise are different than in adults. Aim of Study. The purpose of this study was to investigate the relationship between a) the predicted VO_2max (by a published equation) with the VO_2max measured in the laboratory and b) the velocity at the last stage of Yo-Yo IR1 (YYIR1) with the vVO_2max measured in the laboratory in elite youth soccer players (U17). Material and Methods. Twenty-seven soccer players completed a laboratory treadmill test (LTT) and the YYIR1 which were conducted in random order. Their VO_2max was measured during LTT and had been predicted by the results of the YYIR1 test from a published equation. Results. The values of VO_2max in LTT and YYIR1 were different ($t = -7.652$, $p < 0.001$) (58.9 ± ± 5.3 and 50.8 ± 2.7 ml/kg/min, respectively). There were no differences between the measured values of vVO_2max in LTT and YYIR1 ($t = 1.652$, $p = 0.11$). Also, no differences were observed in HRmax values in the two tests ($t = -0.185$, $p = 0.854$). The equation derived from the results of the present study did not have prediction power ($r = 0.11$, $r^2 = 0.012$). Conclusions. The VO_2max which was predicted by the published equation from the performance of YYIR1 was different from VO_2max was measured in the laboratory in elite youth male soccer players (U17). However, YYIR1 could be used for measuring HRmax and VO_2max velocity.

KEYWORDS: aerobic capacity, football, prediction, maximal oxygen consumption.

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Introduction

Soccer is an intermittent-type of sport that incorporates actions with low and high intensity and duration. The development and use of technology help trainers and scientists to study extensively the physical demands of soccer [25]. In elite youth soccer, distances around 9 km are covered by players, and approximately 10% of this distance is covered in high velocity [2, 9]. Additionally, soccer players perform many other activities in a match, such as accelerations, decelerations, jumps, changes of direction, and others [9]. All of the above actions activate aerobic and anaerobic metabolism which are crucial for soccer players' performance [20].

The aerobic capacity may be assessed with the measure of maximum oxygen uptake (VO_2max), which refers to the maximal ability of the body to use oxygen during maximal effort. The gold standard for assessing VO_2max consists of maximal laboratory tests using a treadmill [12]. Some other indices which were measured during laboratory testing are velocity at which VO_2max occurred (vVO_2max) and the velocity at which RER 1 occurred (vRER1). All of the above indexes can be used for the design and evaluation of aerobic training. Previous researchers have mentioned that vVO_2max is a better indicator of performance than VO_2max because it combines both VO_2max and running economy [14]. As a performance indicator vVO_2max can explain inter-individual differences in performance [17] and can be used to determine optimal training intensity [7]. More specifically if an athlete increases his vVO_2max through training he will also improve his running performance [17].

Thus, laboratory measurement which is the most accurate method requires the use of expensive equipment, well-trained personnel, and a lot of time for measuring large groups of athletes like that of a soccer team. All the reasons mentioned above lead to developing different field tests for VO_2max, vVO_2max and other indexes estimation [4, 23]. Those tests are less accurate but the trainer can measure a lot of players in less time, using much less equipment.

One of the field tests that is commonly used in soccer is the Yo-Yo intermittent recovery test which was devised and developed based on another test, the maximal multistage 20 m shuttle run test (20-MST) [4] which was described for the first time by Léger and Lambert (1982) [23]. Many researchers have studied the correlation between the performance in the Yo-Yo test and VO_2max and some of them have mentioned weak correlations [3, 11] while others moderate to strong correlations [19]. Additionally, previous studies showed that the total distances covered in a match by players and the distances in different velocities are correlated to the players' performance in the Yo-Yo test [10].

Researchers have proposed a couple of equations for the estimation of VO_2max in adults [4] with the use of the total distance or the maximum velocity of the Yo-Yo test. However, the use of these equations for estimating the VO_2max in children may include mistakes. Their physiological adaptations to incremental exercise are different than in adults [27]. Also, youths experience a faster recovery after maximal intermittent bouts of exercise which can affect the performance in this kind of exercise [24]. For the reasons above it is hypothesized that age could be a crucial factor inVO_2max estimation via Yo-Yo test performance.

Aim of Study

The purpose of this study was to investigate a) the relationship between the predicted VO_2max from the results of Yo-Yo IR1 (by the equation proposed by Bangsbo et al., 2008) [4] with the VO_2max measured in the laboratory, and b) the relationship between the velocity at the last stage of Yo-Yo IR1 (YYIR1) and vVO_2max measured in the laboratory. Additionally, the third aim of this study was to produce regression equations enabling the use of YYIR1 distance to predict VO_2max, in elite youth soccer players, aged 15-17 years.

Material and Methods

Subjects

Twenty-seven elite youth soccer players (16.5 ± 1.2 y; 1.73 ± 0.04 m; 68.1 ± 3.4 kg; mean ± SD) participated in the study. Furthermore, all participants and their parents were informed about the potential risks and benefits of the study, and a written consent form was signed by the parents. The local Institutional Review Board approved the study, in the spirit of the Helsinki Declaration.

Procedure

All players completed two tests (an incremental laboratory treadmill test (LTT) and the YYIR1 test) in random order during a 10-day period. The study was conducted before the in-season period. Players' VO_2max was measured during LTT and was estimated from the results of YYIR1. Furthermore, testing was performed under the same conditions and the players were instructed to avoid intense exercise during the 24 hours before the tests.

During their first visit to the laboratory, all players were familiarized with the procedures for the treadmill test and the YYIR1 test. Also, they had their body mass, height, and percentage of body fat measured. During the next two visits (almost 7 days apart), the participants performed the aerobic tests. In the beginning, the soccer players performed a 10-minute warm-up, and at the end a 10-minute cool-down. During the 10 days of the study, the players participated in five training sessions. Additionally, all participants consumed water ad libitum to ensure proper hydration during training and testing.

Anthropometric and assessment of maturity status

Body mass was measured to the nearest 0.1 kg using an electronic digital scale with the participants in their underclothes and barefoot. Standing height was measured to the nearest 0.1 cm (Seca 220e, Hamburg, Germany). Body fat percentage was estimated based on the sum of four (biceps, triceps, suprailiac, subscapular) skinfold thicknesses using a specific caliper (Lafayette, Ins. Co., Indiana) on the right side of the body. The body fat was estimated using the equation of Siri (1956) [28].

Laboratory VO_2max and vVO_2max assessment

VO_2max of soccer players was assessed in the morning. The room temperature was around 22°C and the relative humidity was approximately 50%. The cardiorespiratory VO_2max test was performed on a motorized treadmill (Pulsar, h/p/Cosmos, Nussdorf-Traunstein, Germany). The first stages of the protocol had similar velocities with YYIR1. More specifically the initial grade was 0% and the first stage had a speed of 10 $km \cdot h^{-1}$ for 30 seconds. For the next three stages, the speed was increased every 30 seconds by 1 $km \cdot h^{-1}$. The fifth stages' velocity was 14 $km \cdot h^{-1}$ for 1 minute and was gradually increased in the next stages every 2 minutes until exhaustion. After the final stage, a cool-down session took place for 5 min, at 4 $km \cdot h^{-1}$, and 0% grade. VO_2max values and cardiorespiratory indices were measured via a breath-by-breath automated pulmonary-metabolic gas exchange system (Oxycon Pro, Jaeger, Wurzburg, Germany). Furthermore, prior to all tests, O_2 and CO_2 analyzers were calibrated using certified gas concentrations and the mass flow sensor was automatically calibrated against a 2.0 L calibration syringe. The highest VO_2 value recorded at the maximal exercise intensity, after achieving the stabilization of VO_2 for at least 5 measurements (steady-state), was considered VO_2max. During the testing, also other cardiorespiratory parameters were recorded: heart-rate (HR), maximal HR, and respiratory exchange ratio (RER). The heart rate (HR) was recorded every 5 s throughout the exercise tests using short-range telemetry (Polar H2, Polar Electro Oy, Kempele, Finland).

VO_2max was assumed when at least one out of the four following criteria, was met: a) HR during the last minute exceeded 95% of the expected maximal HR predicted using formula 220-age; b) leveling off (plateau) of VO_2max despite the increase in treadmill grade; c) a respiratory gas exchange ratio (VCO_2/VO_2) equal to or higher than 1.1 was reached; d) the subject was no longer able to continue running despite verbal encouragement.

The lowest running speed that elicits a VO_2 equivalent to VO_2max during the treadmill test was defined as vVO_2max [6]. If the final exercise workload was not completed for 120 s but VO_2 continued to increase then vVO_2max was determined from the following equation [21] (Equation 1):

$$vVO_2max = \text{last workload completed in 120 s} = [(\text{time of the uncompleted work load}/120) \times 1]$$

Yo-Yo intermitted recovery test level 1

The YYIR1 consisted of 2 × 20 m intervals of running interspersed by regular short rest periods (10 s). Furthermore, signals were given by a CD-ROM to control the speed. The player run 20 m forward and he adjusted his speed, so to reach the 20 m marker exactly at the time of the signal. Additionally, a turn was made at the 20 m marker and the player run back to the starting marker, which was to be reached at the time of the next signal. Then the player had a 10 s break for running slowly around the third marker which was placed 5 m behind him. He had to wait at the marker until the next signal. The course was repeated until the player failed to complete the shuttle run two times in a row. The first time, when the start marker was not reached a warning was given ('yellow card'), the second one the test was terminated ('red card'). The last running interval that a player had completed before being excluded from the test was noted, and the test result was expressed as the total running distance covered in the test [11]. The YYIR1 also started at a speed of 10 km/h. Furthermore, in the next 2 speed levels, the speed was increased by 2 and 1 km/h, respectively. Thereafter, the speed was increased by 0.5 km/h at every speed level. The vYo-Yo IR1 was sustained during the last completed 40 m.

VO_2max prediction

Players' VO_2max was predicted from their distance covered in the YYIR1 using the equation recommended by Bangsbo et al. [4] (Equation 2):

$$VO_2max \text{ prediction (ml/kg/min)} = \text{Yo-Yo IR1 distance (m)} \times 0.0084 + 36.4$$

Statistical analysis

Data are presented as means ± SD. Additionally, data normality was verified with the 1-sample Kolmogorov--Smirnov test; therefore, a nonparametric test was not necessary. The scores from the treadmill test and the YYIR1 were compared using a paired T-test. Pearson coefficient was used to verify the correlation between factors of the treadmill test and YYIR1. The relationship between YYIR1 performance and VO_2max

was tested using linear regression analysis. The level of significance was set at $p < 0.05$. SPSS version18.0 was used for all analyses (SPSS Inc., Chicago, IL, USA).

Results

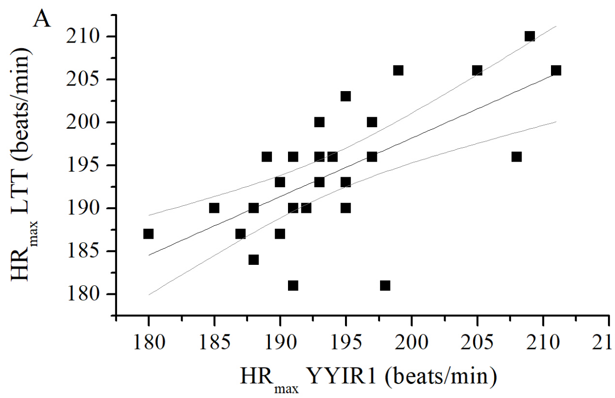
The analysis of the data revealed differences between VO_2max was measured in the laboratory and VO_2max predicted with the use of Equation 1 ($t = -7.652$, $p < 0.001$) (58.9 ± 5.3 ml/kg/min and 50.8 ± ± 2.7 ml/kg/min, respectively). Also, differences were observed in the total duration of the tests (488 ± 89 s for LTT and 852 ± 152 s for YYIR1; $t = 13.075$, $p < 0.001$). There were no differences between the measured values of vVO_2max during LTT and during YYIR1 (4.61 ± ± 0.29 m/s and 4.51 ± 0.14 m/s respectively; $t = 1.652$, $p = 0.11$). Also, no differences were observed in HRmax measured during both tests (193 ± 7.6 beats/min and 193 ± 7.7 beats/min for LTT and YYIR1, respectively; $t = -0.185$, $p = 0.854$) (Table 1).

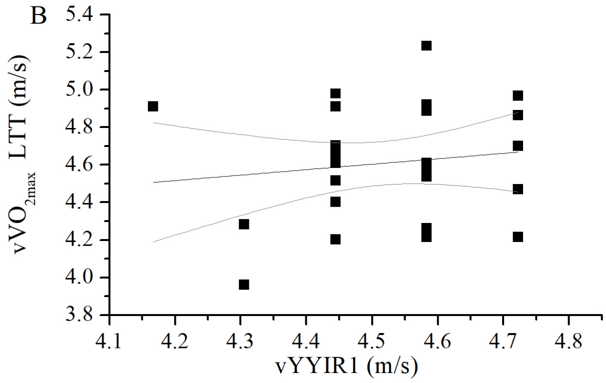
Table 1. Comparison of test results between YYIR1 and LTT (mean ± SD)

Test	Duration (sec)	Maximal velocity (km/h)	HRmax (beats/min)	$\dot{V}o_2max$ (ml/kg/min)	
				Estimated	Measured
YYIR1	852 ± 152	4.5 ± 0.1	193.7 ± 7.6	50.8 ± 2.7	--------
LTT	488 ± 89	4.6 ± 0.3	193.7 ± 7.7	---------	58.9 ± 5.3

Note: YYIR1 – Yo-Yo intermittent recovery test level 1, LTT – maximal laboratory treadmill test, HRmax – maximal heart rate

The correlation coefficient between the two tests (LTT and YYIR1) for HR and velocity were $r = 0.68$ ($p < 0.001$) and $r = 0.13$ ($p = 0.503$), respectively (Figure 1).



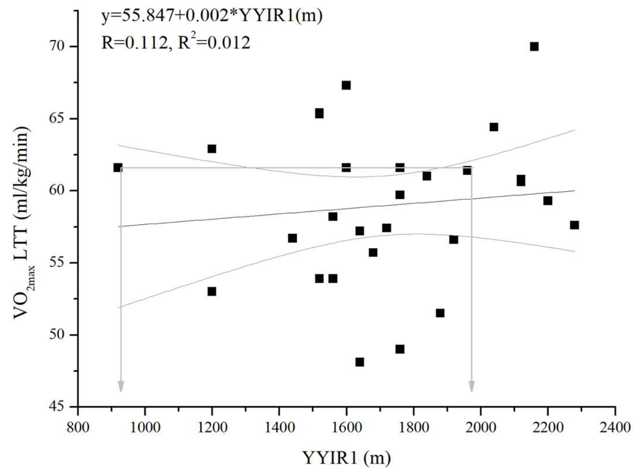


Note: HRmax – maximal heart rate, YYIR1 – Yo-Yo intermittent recovery test level 1, LTT – maximal laboratory treadmill test, vVO_2max – velocity at VO_2max, vYYIR1 – velocity at the last complete level of Yo-Yo intermittent recovery test level 1

Figure 1. Correlation and confidence intervals (95%) between the results of YYIR1 and LTT in A: maximal heart rate and B: maximal running velocity

The equation for the prediction of VO_2max (Equation 3) was based on the linear regression analysis ($r = 0.11$, $r^2 = 0.012$) (Figure 2):

$$VO_2max = 55.847 + 0.002 \times \text{Yo-Yo IR1 (distance m)}$$



Note: The grey lines indicate the variation of the distance covered in YYIR1 (920-1,960 m) for a given VO_2max of ~61.5 ml/kg/min; LTT – laboratory treadmill test, YYIR1 – Yo-Yo intermittent recovery test level 1

Figure 2. Correlation between the VO_2max obtained during LTT and the distance covered in the YYIR1

Discussion

One of the primary aims of this study was to investigate the validity of predicting VO_2max of elite youth male soccer players based on the performance of the YYIR1 test. The results indicated that there were differences between the direct measure of VO_2max and the indirect estimation of VO_2max with the use of Equation 2. The results above confirmed that, in elite male youth soccer players, we can not compare the VO_2max predicted with the use of Equation 2 with the VO_2max measured in the laboratory. Also, the VO_2max measured by the YYIR1 compared to the LTT was underestimated by 15.9%.

Additionally, the results of the present study indicate a non-significant relationship between YYIR1 performance (distance) and LTT VO_2max ($r = 0.112$, $p = 0.572$). To our knowledge, only one study has investigated the relationship between YYIR1 and VO_2max in elite youth male soccer players [18] and showed moderate relationships between a VO_2max measurement and distance covered in the YYIR1. However, many studies were performed in adult soccer players [19] and they mentioned from weak to strong correlations between YYIR1 distance and VO_2max (measured during LTT).

The YYIR1 is a field test which for every 40 m has a 10 s active recovery. This is its main difference from LTT which is a continuous test. Another difference is the energy cost and the ability for maintaining the economy in constant changes of direction in the YYIR1. This diverse running economy could be a reason for the above differences or the lack of relationships [11]. Figure 2 shows that players with similar VO_2max (61.4--61.6 ml/kg/min) may run different distances in YYIR1 (920-1,960 m).

Additionally, one possible explanation for this difference could be different, than in adults, physiological adaptations of children to incremental exercise [27]. More specifically, youths in comparison to adults 1) in all intensities have a greater oxygen consumption per body weight, 2) have higher levels of ventilation per kilogram at submaximal and maximal speeds, 3) have inferior breathing efficiency, and also 4) they have higher heart rates at all exercise levels [27]. In comparison to adults, youths have limited glycolytic ability during high-intensity exercise, while their aerobic metabolism is higher [22]. Furthermore, the levels of muscle oxidative enzymes are increased in youngsters, and this promotes lipid oxidation in energy production. However, aerobic metabolism cannot supply enough energy for high-intensity movements [1, 16, 26]. Finally, youths have faster recovery after maximal intermittent bouts of exercise [16] which can affect the performance in this kind of exercise [24]. Also, recovery time can influence the contribution of metabolic systems to energy production during the next bout [5]. Based on the faster VO_2 kinetics, the greater muscle oxidative enzyme activity, and the increased recovery potential of youths when compared to adults, it is justified to claim that age could be a crucial factor for VO_2max estimation via Equation 2 and the use of YYIR1 performance.

Previous studies have mentioned that for an accurate VO_2max determination the treadmill protocol duration has to last at least 8 minutes [15]. In our study, the average time of our protocol was ~8 min (Table 1) which covers the above condition. Also, the protocols' speed and duration at each level were similar to the characteristics of the YYIR1 test.

The proposed equation 3 has been derived from the data of our study sample. As it hasn't got a prediction power ($r = 0.11$, $r^2 = 0.012$) it is very needed to find a proper equation for elite youth male soccer players. Therefore, further research with more participants is required in this study area. Previous studies that used continued exercise protocols (20 m shuttle run test, Yo-Yo endurance test) have mentioned better prediction indexes of VO_2max than YYIR1 [11, 23].

The vVO_2max could be used in training and it would be very useful if it could be measured during a field test evaluating many athletes simultaneously. Previous researchers showed that vVO_2max is the lowest exercise intensity that could be used for improving aerobic capacity [13]. Also, the increase of vVO_2max through training improves the running speed which corresponds to a given percentage of VO_2max [17].The results of the present study showed that the vVO_2max obtained on the treadmill and vYYIR1 were similar. More specifically, the mean value of vVO_2max was higher by 2.2% (0.1 m/s) than vYYIR1. Furthermore, previous studies have mentioned that overcoming air resistance during field running implies additional energy expenditure reaching to at least 4% of the total expenditure, as compared to treadmill running [8]. Additionally, the changes in direction in YYIR1 increase the energy cost of running. These factors probably can explain the small difference between the two measured velocities. Moreover, the comparable HRmax, attained by the players in both LTT and the YYIR1, shows that they gave their maximal effort during both tests before reaching voluntary fatigue and that the YYIR1 is suitable to determine HRmax in these subjects.

This study presents some limitations that should be mentioned. Firstly, the number of participants was limited and the generalization of our findings should be made with caution. Secondly, probably the use of a mobile ergospirometer would be more proper to measure the VO_2max during the YYIR1 test.

Conclusions

In conclusion, the level of VO_2max predicted with the use of the equation proposed by Bangsbo et al. from the results of YYIR1 was significantly underestimated compaerd to VO_2max measured in the laboratory in elite youth male soccer players (U17). Additionally, the different physiological adaptations of youths to incremental exercise, compared to adults, could be a crucial factor of VO_2max estimation via YYIR1 performance. Finally, because the equation proposed in the current study did not have a prediction power, there is still a need for future studies to form an equation appropriate for youth athletes.

Conflicts of Interest

The authors declare no conflict of interest.

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