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Cardiorespiratory Responses to Yo-yo Intermittent Endurance Test in Nonelite Youth Soccer Players

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Abstract. Castagna, C., F.M. Impellizzeri, R. Belardinelli, G. Abt, A. Coutts, K. Chamari, and S. D'Ottavio. Cardiorespiratory responses to yo-yo intermittent endurance test in nonelite youth soccer players. *J. Strength Cond. Res. 20(2): 326–330. 2006.*—This study examined the validity of the Yo-yo Intermittent Endurance Test (Level 1; YYIET) as indicator of aerobic power in youth soccer players. Cardiorespiratory responses were determined in 18 moderately trained nonelite youth soccer players (age, 16.6 ± 0.8 years; height, 178.7 ± 6.2 cm; body mass, 69.8 ± 6.0 kg; $\dot{V}O_2$peak, 52.8 ± 7.4 ml·kg^{-1}·min^{-1}) while performing the YYIET and an incremental treadmill test. Maximal heart rate (HRmax), respiratory exchange ratio (RER), O_2 pulse, $\dot{V}O_2$peak, and maximal ventilation ($\dot{V}$Emax) were measured. Group YYIET $\dot{V}O_2$peak, HRmax, RER, and O_2 pulse were not significantly different from treadmill responses ($p > 0.05$). $\dot{V}$Emax was significantly lower ($p < 0.05$) during the YYIET compared to the treadmill condition. No significant correlation was found between treadmill $\dot{V}O_2$peak and YYIET performance ($p > 0.05$). This study showed that the YYIET elicits peak $\dot{V}O_2$ and HR responses. However, YYIET performance results were not related to $\dot{V}O_2$peak measured in laboratory. Furthermore, the individual $\dot{V}O_2$peak reached during the TM did not reflect the $\dot{V}O_2$peak obtained during the YYIET, as shown by the large limits of agreement. As a consequence, compared to other shuttle run field tests, YYIET seems to be a weak indicator of aerobic power in youth moderately trained youth soccer player.

Key Words. Field testing, intermittent exercise, aerobic power, football, heart rate

Introduction

It has been clearly demonstrated that measures of aerobic fitness ($\dot{V}O_2$max, lactate-anaerobic threshold, running economy) are related to soccer performance (13). Consequently, the assessment of aerobic fitness on a regular basis is important for monitoring the effectiveness of the physical training program and the preparedness of soccer players to compete.

While the use of laboratory based tests usually provides greater internal validity and reliability, compared with field tests, their use may be problematic for some coaches and fitness trainers simply because of cost or gaining access to laboratory facilities. For these reasons a number of field tests have been designed for use in soccer for the assessment of aerobic fitness (2–6, 10, 16–20, 27, 31).

Of these, the Yo-yo Intermittent Endurance Test (YYIET) has become popular (2, 4, 32). The YYIET is a progressive intermittent shuttle run test that allows 5 seconds recovery following every second 20-m shuttle. Its aim is to progressively illicit a maximal physiological response from players during a soccer specific (intermittent) protocol. Two YYIET versions are currently available, Level 1 and Level 2. Level 1 has been devised for young and-or amateur athletes or habitually active people, while Level 2 is supposed to be used to test the endurance of those who have successfully progressed through all the Level 1 stages (usually well-trained athletes; 5). While the YYIET is widely used in soccer at all competitive levels, only a few studies appear to have addressed the physiological responses to this test. Krustrup et al. (17) studied the physiological responses to the Yo-yo Intermittent Recovery Test, which is similar to the YYIET examined in the present study except that a 10-second recovery is allowed between each second 20-m shuttle and a different speed progression is used. Moreover, those reports that have attempted to address the physiological responses of the YYIET have done so by examining the Level 2 version and-or using elite-level soccer players (24, 28).

Among the components of aerobic fitness (29), $\dot{V}O_2$max has been revealed as an important prerequisite of soccer-specific fitness and a precise indicator as to the minimum level required to play at the elite level suggested for prospective players (9, 32). As a result, coaches and strength and conditioning professionals who deal with youth soccer athletes should rely on valid field tests that could provide as much information as precisely as possible to estimate a player's individual level of $\dot{V}O_2$max(14).

The aim of this study was to examine the cardiovascular response of regional-level soccer players while performing YYIET Level 1 (5) to check its validity as test for the estimation of maximal aerobic power in nonelite youth soccer players. This was thought to be an important issue to be addressed in youth soccer fitness assessment as many field tests have been already proposed for the estimation of $\dot{V}O_2$max in youth soccer (14, 32). Better knowledge of the nature of recently introduced tests such us YYIET may be useful to guide strength and conditioning coaches in properly use of them with young soccer players, avoiding the likelihood of redundant results (14).

METHODS

Experimental Approach to the Problem

In the present investigation, a nonexperimental descriptive correlation design was used to examine the relationship between YYIET and treadmill progressive maximal protocol (8) cardiovascular responses. Eligibility to participate in the study was defined as the inability to progress through all the stages of Level 1 of YYIET (5). This possibility was tested in a preexperiment session with all of the players blinded about the admission criteria of the study. The preexperiment session took place 1 week before the commencement of the experimental procedures. Similar to previous research involving progressive shuttle-run field tests, criterion validity was investigated by plotting YYIET score (distance covered) against treadmill $\dot{V}O_2$peak. Additionally, measurement agreement (direct criterion validity) was assessed comparing YYIET cardiovascular responses to treadmill results (7). Because previous research involving progressive shuttle run field-tests revealed significant relationship between test score (distance covered) and treadmill $\dot{V}O_2$max (17, 19, 22, 31), we assumed as research hypothesis the existence of a significant correlation between criterion variable (treadmill $\dot{V}O_2$peak) and independent variables (YYIET distance and $\dot{V}O_2$peak).

Subjects

Participants were 18 regional-level youth soccer players (age, 16.6 ± 0.8 years; height, 178.7 ± 6.2 cm; body mass, 69.8 ± 6.0 kg; $\dot{V}O_2$peak, 52.8 ± 7.4 ml·kg^{-1}·min^{-1}) chosen from a population of students attending a high school located in the area of Ancona (Istituto Tecnico Industriale Statale "Vito Volterra," Torrette di Ancona, Italy) during the 2001–2002 season. Playing experience of each player was no less than 5 years. They refrained from heavy training for the 2 days preceding testing sessions. During the 2 hours preceding assessments, only ad libitum water intake was allowed, and subjects consumed a light meal at least 3 hours before the commencement of exercise. Familiarization sessions were implemented, allowing players to perform 3–4 minutes of the YYIET. The present investigation was performed approximately 15 days after the end of the regular competitive season. During this period, players underwent mostly skill and tactical training sessions with the same weekly regular-season training schedule (two or three training sessions a week with a friendly match during the weekend) in view of the summer tournaments. Players were well motivated, and throughout testing sessions, verbal encouragement was given by the test leader (C.C.) and by peers to induce maximal effort. Written informed consent was received from all participants and parents after a brief but detailed explanation about the aims, benefits, and risks involved with this investigation. Participants were told they were free to withdraw from the study at any time without penalty. The study was approved by the local ethics committee.

Testing Procedures

Testing sessions were administrated in a random order and consisted of (1) a laboratory test for maximal oxygen uptake (Bruce protocol) (8) performed on a motor-driven treadmill (Cosmed, Rome, Italy) and (2) a YYIET Level 1 performed indoors on a wooden surface.

All laboratory and field gas analyses were performed using the same portable lightweight breath-by-breath gas analyzer (K4b^2; Cosmed, Rome, Italy) to improve data reliability. McLaughlin et al. (23), Pinnington et al. (30), and Duffield et al. (12) have reported the validity, reliability, and accuracy of the K4b^2 portable gas analyzer. Before each testing session, the K4b^2 was calibrated according to manufacturer guidelines (K4b^2 user's manual; Cosmed). Expired gases were monitored online during the field-testing sessions by telemetry. All testing sessions took place at a similar time of day as the usual training session times of the participants. The variables selected for the analysis were peak $\dot{V}O_2$ ($\dot{V}O_2$peak), maximal heart rate (HRmax), peak ventilation ($\dot{V}E$peak), respiratory exchange ratio (RER), and oxygen pulse (O_2pulse).

Peak laboratory physiological values were assessed using a progressive multistage maximal test (8) on a motor-driven treadmill. The highest heart rate achieved at exhaustion was considered as the individual HRmax. Peak oxygen uptake ($\dot{V}O_2$peak) was considered as the mean $\dot{V}O_2$ values measured during the last 15 seconds of exercise. The criteria for attaining $\dot{V}O_2$peak included any two of the following: volitional exhaustion; attainment of the age-predicted HRmax (220 − age); RER equal or greater than 1.15; and a plateau in oxygen consumption (increase less than 2 ml·kg^{-1}·min^{-1}) despite increased exercise intensity.

The YYIET was performed according to the guidelines established by Bangsbo (5). Briefly, the test consists of incremental shuttle running until exhaustion. Every second 20 m, players have 5 seconds of active recovery consisting of 2 × 2.5 m jogging. Running speed (Table 1) is prescribed by bleeps occurring at timed intervals. Players must reach the 20-m line by the time each bleep is heard. The YYIET is terminated when the participant twice fails to reach the front line in time (objective evaluation) or he or she feels unable to cover another shuttle at the dictated speed (subjective evaluation). The YYIET result is the total distance covered. To avoid possible tracking-speed problems (21), audio cues of the YYIET were recorded on a compact disc (CD; www.teknosport.com; Ancona, Italy) and broadcast using a portable CD player. YYIET testing sessions were all performed on a wooden surface to obtain consistent data, because grass conditions may have affected the testing sessions, the research schedule, and YYIET performance.

Statistical Analyses

Mean and *SD* values were calculated for each variable. Normality assumption was checked using the Kolmogorov-Smirnov test and from visual inspection of the normality plot. Comparisons between means of 2 variables were performed using paired *t*-tests. Bland-Altman (1) limits of agreement were used to test the difference between cardiorespiratory responses during yo-yo and treadmill testing. Heteroschedasticity was addressed for each Bland-Altman calculation, and log transformation of variables was considered when necessary. The relationship between different variables was detected using Pearson's product-moment correlation. Spearman *rho* was calculated to assess rank-order measurements of homologues physiological variables (1). Significance was set at $p \leq 0.05$ a priori.

TABLE 1. Yo-yo Intermittent Endurance Test Level 1 protocol.

Stage	Speed (km·h^{-1})	Shuttle bouts (2 × 20 m)	Split distance	Accumulated distance
1	8	2	80	80
2	9	2	80	160
3	10	2	80	240
4	10.5	8	320	320
5	10.75	8	320	640
6	11.0	8	320	960
7	11.25	3	120	1,080
8	11.5	3	120	1,200
9	11.75	6	240	1,440
10	12.0	6	240	1,680
11	12.25	6	240	1,920
12	12.5	6	240	2,160
13	12.75	6	240	2,400
14	13.0	6	240	2,880
15 16 17	13.25 13.5 13.75	6 6 6 6 6 6	240 240 240	3,120 3,360 3,600
18 19 20	14.0 14.25 14.5		240 240 240	3,840 4,080 4,320

After each shuttle-run bout, player performs 5 seconds of active recovery jogging back and forward between two lines (cones) set 2.5 m apart.

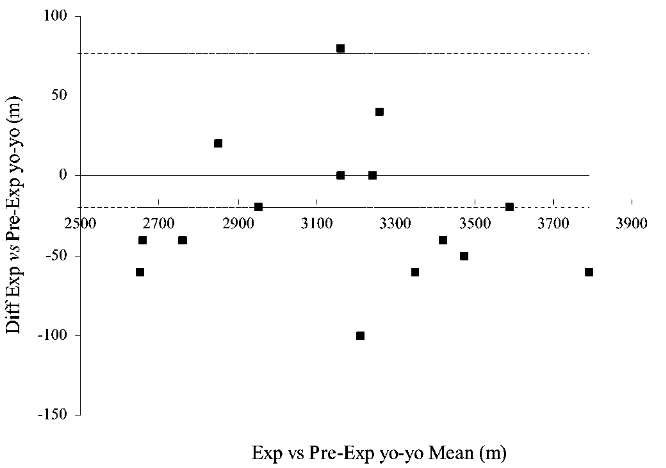

FIGURE 1. Bland-Altman plot of the experiment (Exp; with K4b^2) vs. preexperiment Yo-yo Intermittent Endurance Test (Pre-Exp yo-yo; no K4b^2). Bias = −19.44 m; limits of agreement = −115.58; +76.69 m.

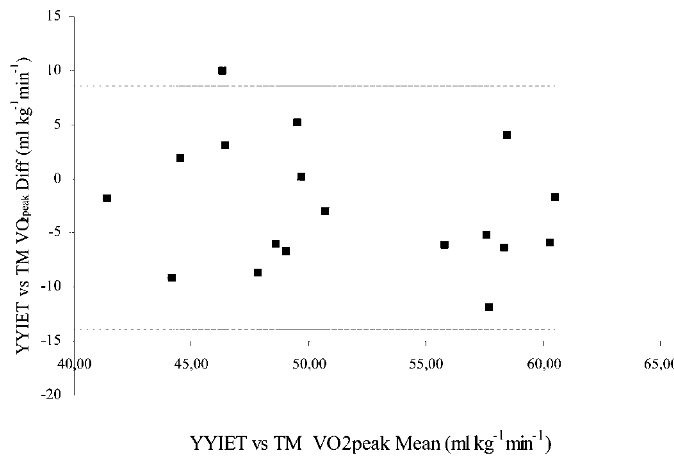

FIGURE 2. Bland-Altman plot of the Yo-yo Intermittent Endurance Test ($\dot{V}O_2$peak) vs. treadmill (TM) values.

RESULTS

The preexperiment YYIET distance was not significantly different from that covered during the experimental condition (3044 ± 442 and 3025 ± 432 m, respectively; $p > 0.05$). A Bland-Altman plot of experimental vs. pre-experimental YYIET performance is shown in Figure 1. Results of the physiological variables of interest are shown in Table 2.

No significant correlations were found between the distance covered during the preexperiment YYIET and treadmill $\dot{V}O_2$peak ($r = 0.49$, $p > 0.05$). YYIET $\dot{V}O_2$peak was not significantly related to the distance covered during the test ($r = 0.53$, $p > 0.05$). Bland-Altman plot of YYIET vs. treadmill $\dot{V}O_2$peak is shown in Figure 2. Quantitative analyses of Bland-Altman statistics are shown in Table 3.

Significant Spearman correlation coefficients were found between YYIET and treadmill $\dot{V}O_2$peak (0.65, $p = 0.003$), HRmax, (0.54, $p = 0.02$), O_2pulse (0.55, $p = 0.04$), and $\dot{V}E$ (0.61, $p = 0.01$).

DISCUSSION

The main finding of this study was that, contrary to other popular multistage shuttle running tests for distance (19, 20, 22, 31), it was not possible to establish significant re-

TABLE 2. Values of the cardiovascular variables of interest.*

Exercise mode	$\dot{V}O_2$peak (ml·kg^{-1}·min^{-1})	HRmax (bpm)	$\dot{V}E$peak (L·min^{-1})	O_2pulse (ml·beat^{-1})	RER
YYIET	50.2 ± 6.1	192 ± 7	136 ± 19	19.8 ± 2.7	1.16 ± 0.04
Treadmill	52.8 ± 7.4	193 ± 8	148 ± 19†	19.4 ± 3.5	1.17 ± 0.03

* YYIET = Yo-yo Intermittent Endurance Test.
† Significantly different from the YYIET results ($p \leq 0.05$).

TABLE 3. Values of Bland-Altman statistic relative to physiological variables (YYIET vs. treadmill).

	YYIET-TM (bias)	95% Limits of agreement
$\dot{V}O_2$peak	−2.67 (p = 0.06)	−13.96; 8.63
HRmax	−0.89 (p = 0.59)	−14.52; 12.74
O_2pulse	0.39 (p = 0.55)	−4.96; 5.74
RER	0.01 (p = 0.77)	−0.08; 0.07

YYIET = Yo-yo Intermittent Endurance Test; TM = treadmill condition.
* $p \leq 0.05$.

lationships between YYIET performance (distance covered) and treadmill $\dot{V}O_2$peak. This means that YYIET performance (Level 1) is not solely determined by an individual's maximal aerobic power. This finding is in agreement with Oliveira et al. (28), who studied YYIET Level 2.

The maximal respiratory variables during the treadmill and field test were not significantly different, showing that YYIET Level 1 elicited a maximal response. However, $\dot{V}O_2$peak during the YYIET tended to be lower compared to TM. Mean YYIET $\dot{V}$Epeak showed a significantly lower value compared to the treadmill condition, despite similar RER values. It is unclear why $\dot{V}$Epeak would be lower during the YYIET compared to the treadmill when all other respiratory values were similar. Probably, the nature of the treadmill protocol (8) involving a progressive increment of treadmill inclination may has affected $\dot{V}$E responses. Although no significant differences were found for group $\dot{V}O_2$peak (Table 2), Bland-Altman statistics (Table 3; Figure 2) showed that at individual differences may be large. In this regard individual differences higher than ± 10 ml·kg^{-1}·min^{-1} were found (see Table 3). These differences should be regarded as very large and intolerable for direct aerobic power assessment. Resulting this, provided the availability of a portable gas analyzer, it is suggested to use other field test protocols to evaluate individual $\dot{V}O_2$peak in soccer players (6, 15, 16).

No significant difference was found between total distances covered with or without the K4b^2 gas analyzer during the YYIET. As the experimental condition performance (wearing K4b^2) was not significantly different from that obtained in the admission test (no K4b^2), the cardiorespiratory responses measured during the YYIET can be assumed as a direct reflection of the cardiovascular responses that took place during the test. This lends support to the value of this research design that aimed to directly examine the cardiorespiratory responses of YYIET. Furthermore, this finding revealed a good reproducibility of YYIET not previously addressed in other studies with state of the art statistical analysis (7).

While it is difficult in the current study to determine the factors other than $\dot{V}O_2$peak affecting the distance covered during the YYIET, these influencing factors may be related to the ability of the player to engage in shuttle running per se. Consequently, the ability to accelerate, decelerate and turn may contribute to performance during the YYIET. Given that this type of activity is observed in competitive soccer (35) whatever the level of competition is (11), it could be speculated that players with better YYIET performance may be more efficient during actual match play. However, this could be only confirmed with physiological measurements coupled with match and time motion analyses.

Our results showed that during the YYIET the aerobic energy system is heavily taxed and that the neuromuscular requirements caused by the direction changes could be similar to those involved during actual match play. These characteristics could suggest that the YYIET can be used as indicator of aerobic-specific endurance more than generic aerobic power. However, using an intermittent progressive shuttle running protocol similar to the YYIET Level 1, Krustrup et al. (17) and Mohr et al. (25) found in adult professional soccer players good correlations between test performance (distance covered) and physical match-performance during actual match-play. Furthermore Yo-yo Intermittent Recovery Test performance (17) showed to be correlated with $\dot{V}O_2$max also. In light of the finding of these studies (17, 26), it seems that the Yo-yo Intermittent Recovery Test, more than the YYIET, could be a valid for soccer-specific endurance. Although Krustrup et al. (17) and Mohr et al. (26) studied adult professional players, youth soccer has been reported to impose similar physiological demands on players (4, 11, 33). Therefore, the Yo-yo Intermittent Recovery Test may be conveniently used in youth soccer players too. However, this inductive reasoning should be confirmed by appropriate validation studies.

In conclusion, the YYIET Level 1 has not proved to have indirect criterion validity as no significant correlations have been found between treadmill $\dot{V}O_2$peak and YYIET distance. Furthermore, the individual $\dot{V}O_2$peak reached during the TM did not reflect the $\dot{V}O_2$peak obtained during the YYIET Level 1, as shown by the large limits of agreement. As a consequence, compared to other shuttle run field tests, YYETL1 cannot be considered a valid test for aerobic power in youth moderately trained soccer player.

PRACTICAL APPLICATIONS

YYIET has revealed as a suitable testing protocol for assessing individual HRmax. However, as expected the individual HRmax has been attained near to exhaustion, condition that occurred on average after 1290 ± 172 s during YYIET. This is a considerable longer time than that observed during continuous multistage shuttle fitness tests used with soccer players of similar age and fitness level, that showed to induce HRmax responses at exhaustion (34). Resulting this when testing-time is a concern we strongly suggest the use of continuous shuttle running test such as those proposed by Léger et al. (19, 22) and Ramsbottom et al. (31) when dealing with young nonelite soccer players possessing a training status and age similar to those of this study.

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