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Yo-Yo intermittent recovery test level 2: Cardiorespiratory response and performance in professional soccer players, comparison between under 20 and over 20 years old players

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ABSTRACT

Purpose: The aim of this study was to compare the older players (O20) and the younger ones (U20) of the Colombian Professional National League 2015 champion team in cardiopulmonary responses and performance, using the Yo-Yo Intermittent Recovery Test level 2 (YYIR2). Methods: Nine O20 and nineteen U20 were voluntarily evaluated. All subjects were monitored for heart rate, and a continuous breath-to-breath recording was carried out while they performed the YYIR2. The Student T test and the Pearson correlation were used for the statistical analysis. Results: A significant difference in distance covered and speed in the ventilatory threshold between U20 players (280 ± 85,3 m) (16,6 ± 0,3 $km.h^{-1}$) and O20 players (373 ± 113,1 m) (17 ± 0,3 $km.h^{-1}$) was observed. Only in the U20 group, a significant correlation between the variables oxygen uptake in the ventilatory threshold ($\dot{V}O_2atVT$) and performance in the test (D_{max}), $\dot{V}O_2$ at VT and maximum speed (S_{max}), peak oxygen uptake ($\dot{V}O_{2peak}$) and S_{max} and $\dot{V}O_{2peak}$ and D_{max} was observed. Conclusion: The only variables that differentiated the performance in the population was the analysis of the

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distance and the speed at the time of the ventilatory threshold. **Key words**: COLOMBIAN, SOCCER PLAYERS, AEROBIC FITNESS, YO-YO INTERMITTENT RECOVERY TEST.

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INTRODUCTION

In soccer, aerobic fitness is associated with sports performance. The relevance of this for soccer players has been reported by studies that have showed a relationship among the maximum oxygen uptake or aerobic power (VO_{2max}), ventilatory threshold (VT) and the level of performance of players and / or teams (Mohr et al., 2003; Stølen et al., 2005; Impellizzeri et al., 2005). Helgerud et al. (2001) found that aerobic training can improve some aspects of sports performance. It has also been reported that aerobic capacity helps recovery during high intensity intermittent exercise, characteristic of soccer performance and training (Tomlin and Wenger, 2001).

Different studies have found that soccer requires players to repeatedly perform high- intensity actions with brief recovery periods (Di Salvo et al., 2009). A sprint in a soccer match occurs approximately every 90 seconds and lasts between 2 to 4 seconds. In addition, the sprints can constitute between 1 to 11% of the total distance covered during a match, since each player can change motor activity every 4 to 6 seconds (Stølen et al., 2005). Mohr et al. (2003) reported that the amount of high intensity activity that a player is capable of performing is one of the variables that separates players with different levels of sports performance.

Measuring the specific aerobic fitness of a soccer player through an intermittent test has been proposed (Castagna et al., 2009; Lemmink et al., 2004). Yet, although laboratory treadmill tests are considered the gold standard, they present practical, analytical and cost-benefit difficulties (Castagna et al., 2006). On the contrary, a relationship with sports performance has been observed in intermittent field tests, due to the specificity of their movement parameters (Castagna et al., 2006; Castagna et al., 2009; Lemmink et al., 2004).

In the last decades, one of the most popular tests used, which has yielded the broadest scientific evidence, is the Yo-Yo Intermittent Recovery Test (YYIR), created by Jens Bangsbo (Bangsbo, 1994) under the rationale described above. There are two levels of the test. Level 1 (YYIR1) starts at a lower speed and the speed increases are lower compared to Level 2 (YYIR2). For this reason, there has been an association between YYIR1 and aerobic endurance capacity, while YYIR2 has been associated with the ability to perform high intensity intermittent exercise with an aerobic and anaerobic energy demand (Castagna et al., 2006; Castagna et al., 2009; Krustrup et al., 2006; Bangsbo et al., 2008; Karakoç et al., 2012). For example, greater accumulation of lactate in blood and muscle has been found during YYIR2, compared to YYIR1 (Krustrup et al., 2006). It has also been reported that YYIR2 causes a higher peak in blood lactate concentration, lower levels of phosphocreatine and lower muscle pH (Krustrup et al., 2006; Bangsbo et al., 2008), suggesting a higher anaerobic contribution than YYIR1.

Despite this, the relationship between performance in both levels of the test and aerobic fitness is not clear (Bangsbo et al., 2008; Karakoç et al., 2012). For example, Krustrup et al. (2003), Thomas et al. (2006) and Rampinini et al. (2010) found a strong correlation between YYIR1 and VO_{2max} performance; Castagna et al. (2006) found no correlation and Karakoç et al. (2012) found a moderate correlation. As for YYIR2, Rampinini et al. (2010) found a weak correlation, while Krustrup et al. (2006) and Karakoç et al. (2012) found a moderate correlation.

Most studies compare cardiopulmonary responses and / or aerobic fitness with performance in the field test, making comparisons between the values obtained directly in a laboratory treadmill test, with the subsequent performance in the field test, without direct measurement of oxygen uptake in the latter, which would be an error due to the difference in the type of effort performed in both tests (Castagna et al., 2006). For example, Aziz et al. (2005) compared two protocols of continuous and intermittent type tests and reported that between the tests only shared a common variance of 40%, which indicates that the performance in any of the tests may not be interchangeable. Likewise, Lemmink et al. (2004) found that the test that clearly distinguished the different levels of sports performance of soccer players was the intermittent protocol one.

For this reason, it would be important to know which is the cardiopulmonary response measured directly from YYIR2 and its role in test performance.

So far, we have not found a study reporting the cardiopulmonary responses to YYIR2 and the performance on the test with Colombian soccer players. Bearing in mind that the Colombian soccer team ranked third in the world, according to the FIFA world ranking (2014), and that team also has world-class players in the main soccer leagues of the world, it would be useful to know more about this type of information, in order to have a framework of comparison with players of other latitudes.

On the other hand, YYIR studies have been conducted among players of different performance levels (Ueda et al., 2011), ages or stages of development (Veale et al., 2010; Markovic and Mikulic, 2011), or season moment (Mohr and Krustrup, 2011), using both levels of the test. But, to our knowledge, there is no study that compares players with the same level of performance (elite-level professionals) by age in YYIR2.

For this reason, the aim of this study was to compare the older players (over 20 years of age) and the younger ones (under 20 years old) of the Colombian Professional National League 2015 champion team in terms of their cardiopulmonary responses to YYIR2 and performance in the test. The initial hypothesis was that, according to available information, the older players would have a better test performance, therefore a better cardiopulmonary response than the younger players.

METHODS

Subjects

Twenty-eight (28) players from a First Division soccer club of the Colombian Professional Soccer League were voluntarily evaluated, of which nine (9) were over twenty (four defenders, three midfielders and two forwards) and nineteen (19) were under twenty years of age (ten defenses, four midfielders and five forwards). All the subjects were field players of the squad of the champion team of the Colombian National Professional League 2015; the goalkeepers were not included in the study. All players usually trained six times per week, in daily sessions of between 90 to 120 minutes, played at least one official match, and had belonged to the professional team for at least one year. All had previous experience with the test. The study was carried out as part of the training program, under the supervision of the coaches and with the approval of the club's executives. Subjects were informed verbally and in writing about possible risks and benefits, and all signed an informed consent. This study was carried out under the codes of ethics of the Declaration of Helsinki and was approved by the Institutional Ethics Committee.

Two groups were defined to make the comparison, according to age, one younger than 20 years (U20) and another older than 20 years (O20). The variables taken into consideration were peak heart rate (HR_{peak}), heart rate at the ventilatory threshold (HR in VT), percentage of peak heart rate at the ventilatory threshold (%HR_{peak} in VT), peak oxygen uptake (VO_{2peak}), oxygen uptake in the ventilatory threshold (VO_2 in VT), percentage of peak oxygen uptake in the ventilatory threshold (%VO_{2peak} in VT), test performance (D_{max}), distance covered in the ventilatory threshold (D_{VT}), percentage of test performance in the ventilatory threshold

(%D_{max} in VT), maximum speed (S_{max}), speed in the ventilator threshold (S_{VT}) and percentage of maximum speed in the ventilatory threshold (%S_{max} in VT).

Methodology

Test YYIR2

The method used in previous studies was also used for this study (Ingebrigtsen et al., 2014; Bradley et al., 2014). The YYIR2 is a maximum test of incremental speed controlled by an audio, in which the subjects had to perform 2 x 20 meters in a shuttle race. They had an active recovery period of 10 seconds, consisting of a shuttle run of 2 x 5 meters between stages. The test started at a speed of 13 km. h^{-1}, and increased by 2 km. h^{-1} after the first stage and by 1 km. h^{-1} after the second stage, then continued increasing by 0.5 km. h^{-1} after each stage until exhaustion. The test was completed at the time the player did not reach the finish line in the required time, twice consecutively, or voluntarily stopped.

The test performance for each player (D_{max}) was recorded, which comprised the final distance covered by the player during the test, measured in meters; the distance that the player had in the ventilatory threshold (D_{VT}), his percentage expression (% D_{max} in VT), the maximum speed reached in $km \cdot h^{-1}$ by each player (S_{max}), the speed that the player carried in the ventilatory threshold (S_{VT}), and his percentage expression (%S_{max} in VT).

Peak oxygen uptake

$\dot{V}O_{2peak}$ was defined as the highest amount of oxygen during the test, expressed in $ml \cdot kg^{-1} \cdot min^{-1}$; the second ventilatory threshold was defined as an increase in the ventilatory equivalent for oxygen ($\dot{V}E$ / VO2), together with an increase in the ventilatory equivalent for carbon dioxide ($\dot{V}E$ / $\dot{V}CO2$) (Wasserman et al., 2005).

Procedures

The tests were carried out during the preseason, in June. The subjects were instructed to maintain their habitual nutritional intake the day before the test would be administered; they were also asked to refrain from consuming food and beverages (other than water) for 2 hours before each testing session, with a sleep period of at least six hours, without consumption of stimulants or alcoholic beverages; they were instructed not to perform intense physical activity 24 hours previously to test administration. The tests were conducted in a week (13 – 17 June) between 9:00 a.m and 12:00 p.m. All the tests were performed at the same facilities with similar environmental conditions throughout the week. Before performing the tests, the players were asked to try their best and were verbally encouraged to run as long as possible.

Between 8:00 a.m. and 9:00 a.m., weight was recorded on a Tanita BC-585F FitScan Body Composition Monitor®, and size on a CE 0123 UK® DRY stadiometer. Subsequently, each player completed a 15-minute warm-up, prior to taking the test, led by the team's physical trainer. This consisted of 10 minutes of continuous shuttle running with joint mobility exercises in upper and lower limbs, in a space of 20 meters, at an average intensity of 7 km. h^{-1}, and was completed with 10 sprints of 20 meters, 5 with changes of direction and 5 without direction changes; each sprint was followed by a 2-minute recovery period.

During the test, all subjects were monitored for heart rate with a Polar RS800CX® heart rate monitor. In addition, a continuous breath-to-breath recording was performed, using a Cosmed K4b2® ergospirometer until the end of the recovery period, which was calibrated according to the manufacturer's recommendations, before each execution.

Statistical Analysis

The Shapiro-Wilk test was used for the analysis of normality; the statistical analysis was parametric, with the Student T test and Pearson correlation. A *p*-value ≤ 0.05 was used. The data are expressed in mean and standard deviation. The statistical package used for calculations was SPSS® version 24.0 for Windows®; Chicago, IL, USA.

RESULTS

U20 and O20 players showed similar anthropometric characteristics (Table 1).

Table 1. *Physical characteristics of the group of players who participated in the study*

	Age (years)	Weight (kg)	Height (cm)
U20 (n = 19)	18.8 (0.9)*	73.4 (4.7)	179.3 (6.2)
O20 (n = 09)	23.8 (2.3)	76.4 (7.0)	180.4 (6.1)

Note. Data expressed in mean (standard deviation)
** p < 0.001 when compared with the senior group.*

The results of the physiological variables, speeds and distances covered during YYIR2 are presented in Table 2. A significant difference in D_{VT} between U20 players (280 ± 85.3 m) and O20 players (373 ± 113.1 m) ($p = 0.02$) was observed, as well as a significant difference in S_{VT} between U20 players (16.6 ± 0.3 km. h^{-1}) and O20 players (17 ± 0,3 km. h^{-1}) ($p = 0.01$).

Table 2. *Physiological variables, speed and distance covered in the YYIR2 test*

	O20	U20	Significance (*p*-value)
HR_{peak} (b. min^{-1})	182.1 (13.1)	186.2 (5.8)	0.38
HR at VT (b. min^{-1})	177.3 (17.1)	180.6 (5.2)	0.58
$\%HR_{peak}$ at VT	97.2 (3.9)	97.0 (2.8)	0.87
$\dot{V}O_{2peak}$ (ml. kg^{-1}. min^{-1})	55.3 (3.8)	52.7 (5.8)	0.24
$\dot{V}O_2$ at VT (ml. kg^{-1}. min^{-1})	51.0 (2.7)	48.7 (5.5)	0.25
$\%\dot{V}O_{2peak}$ at VT	92.4 (5.6)	92.3 (5.2)	0.99
D_{max} (m)	528.8 (103)	475.7 (70.4)	0.18
D_{VT} (m)	373.3 (113.1)*	280.0 (85.3)	0.02
$\%D_{max}$ at VT	70.4 (15.2)*	58.4 (12.6)	0.03
S_{max} (km. h^{-1})	17.3 (0.2)	17.3 (0.2)	0.86
S_{VT} (km. h^{-1})	17.0 (0.3)*	16.6 (0.3)	0.01
$\%S_{max}$ at VT	98.3 (1.5)*	96.2 (1.6)	0.003

Note. Data expressed in mean (standard deviation).
** p < 0.05 when compared with the U20 group.*

Only in the U20 group, a significant correlation between the variables $\dot{V}O_2$ at VT and D_{max}, $\dot{V}O_2$ at VT and S_{max}, $\dot{V}O_{2peak}$ and S_{max} and $\dot{V}O_{2peak}$ and D_{max} (Table 3) was observed.

Table 3. *Pearson correlation (r) between physiological and mechanical variables in the YYIR2 test for the over 20 group.*

	HR_{peak}	HR at VT	$\%HR_{peak}$ at VT	$\dot{V}O_{2peak}$	$\dot{V}O_2$ at VT	$\%\dot{V}O_{2peak}$ at VT	D_{max}	D_{VT}	$\%D_{max}$ at VT	S_{max}	S_{VT}	$\%S_{max}$ *at VT*
HR_{peak}		0.9										
(*p* value)		0.00										
HR at VT	0.9		0.7									
(*p* value)	0.00		0.02									
$\%HR_{peak}$ at VT		0.7										
(*p* value)		0.02										
$\dot{V}O_{2peak}$												
(*p* value)												
$\dot{V}O_2$ at VT												
(*p* value)												
$\%\dot{V}O_{2peak}$ at VT												
(*p* value)												
D_{max}										0.7	0.6	
(*p* value)										0.02	0.05	
D_{VT}									0,7	0.7	0.9	0,7
(*p* value)									0,01	0.03	0.00	0,02
$\%D_{max}$ at VT								0,7			0,7	
(*p* value)								0,01			0,02	
S_{max}							0.7	0.7			0.7	
(*p* value)							0.02	0.03			0.02	
S_{VT}							0.6	0.9	0,7	0.7		0,7
(*p* value)							0.05	0.00	0,02	0.02		0,01
$\%S_{max}$ *at VT*								0,7			0,7	
(*p* value)								0,02			0,01	

Table 4. *Pearson correlation (r) between physiological and mechanical variables in the YYIR2 test for the sub 20 group.*

	HR_{peak}	HR at VT	$\%HR_{peak}$ at VT	$\dot{V}O_{2peak}$	$\dot{V}O_2$ at VT	$\%\dot{V}O_{2peak}$ at VT	D_{max}	D_{VT}	$\%D_{max}$ at VT	S_{max}	S_{VT}	$\%S_{max}$ *at VT*
HR_{peak}		0.5	-0.5									
(*p* value)		0.02	0.01									
HR at VT	0.5											
(*p* value)	0.02											
$\%HR_{peak}$ at VT	-0.5					0.7			0,5			0,6
(*p* value)	0.01					0.00			0,01			0,00
$\dot{V}O_{2peak}$					0.8		0.6			0.5		
(*p* value)					0.00		0.00			0.01		
$\dot{V}O_2$ at VT				0.8			0.6			0.5		
(*p* value)				0.00			0.00			0.02		
$\%\dot{V}O_{2peak}$ at VT			0.7									0,4
(*p* value)			0.00									0,04
D_{max}				0.6	0.6			0.6		0.8	0.7	
(*p* value)				0.00	0.00			0.00		0.00	0.00	
D_{VT}							0.6		0,8	0.4	0.9	0,6

(*p* value)					0.00		0,00	0.04	0.00	0,00
%D_{max} at VT	0,5					0,8			0,7	
(*p* value)	0,01					0,00			0,00	
S_{max}		0.5	0.5		0.8	0.4			0.5	
(*p* value)		0.01	0.02		0.00	0.04			0.01	
S_{VT}					0.7	0.9	0,7	0.5		0,7
(*p* value)					0.00	0.00	0,00	0.01		0,00
%S_{max} *at VT*	0,6			0,4		0,6			0,7	
(*p* value)	0,00			0,04		0,00			0,00	

DISCUSSION

The main result of this study was that the D_{VT} and S_{VT} covered by O20 players in YYIR2 was higher, compared with U20 players.

Peak oxygen uptake

Reilly (2001) reported that oxygen uptake is the most used variable to characterize soccer players from a physiological point of view, and that these values in both professionals and semi-professionals range from 55 to 68 ml. kg^{-1}. min^{-1} (Bangsbo, 1994), being dependent on each player's tactical position and their aerobic capacity (Rampinini et al., 2010; Fornaziero et al., 2009; Higino et al., 2017). The mean obtained from $\dot{V}O_{2peak}$ from direct measurement during YYIR2 in the present study (55.3 ± 3.8 ml. kg^{-1}. min^{-1} and 52.7 ± 5,8 ml. kg^{-1}. min^{-1} for the O20 group and the U20 group, respectively) coincide with the ranks of $\dot{V}O_{2max}$ reported for professional soccer players by Bangsbo (1994) and Reilly (2001) in continuous treadmill tests. To our knowledge, there are no studies that have measured oxygen uptake directly in YYIR2; thus, it was found that measurements were performed with ergospirometer, during a maximal continuous incremental test in treadmill, being the values of $\dot{V}O_{2max}$ higher than those observed in our study (Castagna et al., 2009; Bangsbo, 1994; Mohr and Krustrup, 2014; Tomlin and Wenger, 2001). This behavior may be due to the intermittent nature of the field test, which differs from the continuous character of the effort in the treadmill test (Castagna et al., 2006; Aziz et al., 2005; Lemmink et al., 2004).

Likewise, when comparing differences in $\dot{V}O_{2max}$ between groups, Rampinini et al. (2010), Ueda et al. (2011), and Chuman et al. (2011) found no difference between elite vs. amateur players. These results are similar to the findings in this study, in which no significant difference in $\dot{V}O_{2peak}$ between professional U20 and O20 players was not found either.

Performance in YYIR2

Ueda et al. (2011), Chuman et al. (2011), Rampinini et al. (2010), and Krustrup et al. (2006) reported significant differences between groups of elite vs. non-elite soccer players in performance, measured as final distance in the YYIR2, being the elite the ones with the longest distance covered. Our results did not show significant differences between the two groups, probably because all the soccer players who performed the test were professionals. This fact would possibly explain the little difference in their final performance in the YYIR2.

Peak oxygen uptake, ventilatory threshold and performance in YYIR2

Wells et al. (2014) found no difference between professional and amateur players in $\dot{V}O_{2max}$, but they did in the final distance covered in YYIR2; our results didn't show differences in D_{max} or S_{max}; but in D_{VT} and S_{VT}

between U20 and O20 players, even though in this case all of them were professionals and familiar with the test.

As for the correlation between the performance in intermittent field tests and the $\dot{V}O_2$ measured in treadmill, Castagna et al. (2006), Chuman et al. (2011), and Wells et al. (2014) found no significant relationship when they compared $\dot{V}O_{2max}$ and YYIR2 performance measured as final distance covered. On the other hand, Rampinini et al. (2010), Ueda et al. (2011), Karakoç et al. (2012), and Bangsbo et al. (2008) found a low or moderate degree of association between $\dot{V}O_{2max}$ and the final distance. In this study, a positive correlation in the U20 group was found between the variables that reflect the internal load or cardiorespiratory fitness ($\dot{V}O_{peak}$ and $\dot{V}O_2$ at VT) and those that reflect the external load or the performance in the test (D_{max} and S_{max}), but not in the O20 group. This behavior of the relationship between $\dot{V}O_2$ and the performance in the YYIR2 suggests that factors such as the ability to change direction and acceleration, which depend more on the capacity of application of the force of the lower limbs, could be determining in the performance of intermittent activities in the O20, compared to U20 players, who are more dependent on their aerobic capacity (Pasquarelli et al., 2010).

Ahmaidi et al. (1992), suggest that the differences in the values obtained in the different tests could be related to biomechanical factors and the energy expenditure efficiency, possibly because of the recruitment pattern of fibers, being more efficient for a specific intensity task, and a higher recruitment of type I fibers than type II (Mauger and Sculthorpe, 2012). This suggests that it is insufficient to consider just $\dot{V}O_{2max}$ as the only variable to qualify performance in high-intensity, intermittent activities (Ueda et al., 2011; Denadai et al., 2004; Bassett and Boulay, 2000).

The VT has been used to evaluate performance (Bassett and Boulay, 2000). For example, Ueda et al. (2011) showed that the relative and absolute $\dot{V}O_2$ in the VT was significantly higher in the elite vs. non-elite population in a group of soccer players, in addition to a strong association between the VT and the performance in the YYIR2. Our results showed no significant differences in the $\dot{V}O_2$ at VT between the groups; however, when analyzing the D_{VT} and de S_{VT} of both groups, significant differences were observed between them, being greater the D_{VT} and S_{VT} for the O20 players. One factor that could explain this behavior is a greater movement economy (or running economy) in the O20 group, similar to the one found by Chamari et al. (2005), who reported a higher economy in senior elite soccer players when compared to juveniles. On the other hand, other authors reported a significant association between the velocity in the VT obtained in a treadmill continuous incremental test and the final distance covered in the YYIR2 (Roe and Malone, 2016). This suggests that the economy of movement seen as distance covered during VT, and its velocity, could be differentiating factors in performance in intermittent activities (Roe and Malone, 2016).

CONCLUSIONS

In this study, it was observed that the only one variable that differentiated the performance in the population was the distance and speed at the time of the VT, measured through spirometry in the YYIR2 test; a better ability to apply force to perform intermittent actions such as changes of direction in the more experienced group of players could explain this behavior. However, the YYIR2 is an indirect measurement field test of $\dot{V}O_{2max}$, so the determination of the VT requires a direct measurement with ergospirometer, which brings with it limitations in its execution due to the need for high technology equipment and personnel trained to perform and interpret the data. This is why in order to make measurements of the VT in a field test, it is necessary to develop indirect low cost- methods which can be practical in their application. Additionally, for future research it is suggested to evaluate the degree of association between the VT measured in the YYIR2 and the performance of soccer players.

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The experiments carried out in this study comply with the laws in force in the country in which they were made.

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