European Journal of Sport Science

ISSN: 1746-1391 (Print) 1536-7290 (Online) Journal homepage: http://www.tandfonline.com/loi/tejs20

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European Journal of Sport Science, 2014
Vol. 14, No. S1, S148–S156, http://dx.doi.org/10.1080/17461391.2012.664171

Routledge
Taylor & Francis Group

ORIGINAL ARTICLE

Physical match performance of youth football players in relation to physical capacity

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Abstract
The aims of the study were to (1) analyse the activity profile of youth football players during competitive matches, and (2) examine the relationship between physical match performance and intermittent exercise performance as well as $\dot{V}O_{2max}$. Thirty youth male football players, aged 14–17 years, carried out a laboratory treadmill test for determination of $\dot{V}O_{2max}$ as well as the Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) and Yo-Yo intermittent endurance level 2 (Yo-Yo IE2) tests. Time–motion analysis and heart rate (HR) recordings were performed during two competitive matches per player. Distance covered during the match was 6311 ± 948 (range: 4435–8098) m, of which 12% were high-intensity activities (HIA; 759 ± 437 [374–2062] m), and 5% was backwards running (309 ± 205 [12–776] m). Mean match HR was 168 ± 12 (140–187) bpm, corresponding to 85% (69–91) of maximum HR. The total distance covered in the last 13.3-min period of the match was 40%, 26% and 17% lower than in the first, second and fourth 13.3-min periods of the match, respectively ($P < 0.05$). The distance covered in backwards running decreased by 31% and 37% from the first to the last 13.3-min periods of the first and second half, respectively ($P < 0.05$). The Yo-Yo IR1 was significantly associated with the time spent with sprinting during the match ($r = 0.63$; $P = 0.002$) and during the last 13.3-min period ($r = 0.63$; $P = 0.022$). Both Yo-Yo IR1 and Yo-Yo IE2 were correlated with the time spent with match HIA ($r = 0.56$ and $r = 0.57$, respectively; $P < 0.05$). No significant relationship was observed between $\dot{V}O_{2max}$ and match time–motion variables ($r = -0.13$–0.25; $P > 0.05$) or Yo-Yo test performances ($r = 0.09$–0.26; $P > 0.05$). In conclusion, youth football players have a high heart-rate loading during match play and a decreased running performance towards the end of the game. The intermittent exercise capacity, as determined in the Yo-Yo IR1 test, appears to be a valid indicator of high-intensity exercise performance in youth matches.

Keywords: *Time–motion analysis, heart rate, Yo-Yo tests, aerobic capacity, adolescents, association football*

Introduction

Adult elite football players cover 9–12 km during an official match, of which 1.5–3.3 km is high-intensity running (HIR; Mohr, Krustrup, & Bangsbo, 2003). Football players demonstrate impaired performance during various phases in a game; the ability to perform intense exercise is deteriorated towards the end of matches, as well as immediately after the most intense periods of the game (Krustrup, Mohr, Steensberg, et al., 2006; Krustrup, Zebis, Jensen, & Mohr, 2010; Mohr, et al., 2003). These data highlight the importance of intermittent endurance performance, which is an important physical fitness component related to the ability to sustain high work rates throughout training sessions and match play (Reilly, Bangsbo, & Franks, 2000; Stolen, Chamari, Castagna, & Wisloff, 2005; Vaeyens, Lenoir, Williams, & Philippaerts, 2008).

Physical match performance of adult football players and the relationship between match locomotor activities and physical capacity is extensively

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documented (Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mohr et al., 2003), but less examined and described in youth populations (Carling, Bloomfield, Nelsen, & Reilly, 2008). Recent studies with youth football players aged 13–18 years have suggested an association between training status and physical performance during match play (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Castagna, Impellizzeri, Cecchini, Rampinini, & Alvarez, 2009; Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010).Under-17 elite football players cover 5–7 km during an official match, of which ~15% (0.4–1.5 km) with high-intensity activities (HIA), and the ability to perform in intermittent fitness tests was related to the total distance covered, as well as with the distance covered in HIR (Castagna et al., 2009, 2010). To add further to the existing data, it would be of interest to study the running performance in different phases of youth football matches and to correlate the physical match performance to a variety of field and laboratory fitness assessments.

Laboratory and field tests have been widely used to assess endurance in football players (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006; Krustrup et al., 2003). Laboratory incremental treadmill tests are usually used to accurately measure aerobic power (Metaxas, Koutlianos, Kouidi, & Deligiannis, 2005) as an indicator of aerobic fitness levels. However, laboratory tests are time consuming and require high levels of personal and technical support and are not football-specific measurements (Bangsbo, Iaia, & Krustrup, 2008). Conversely, field tests such as the Yo-Yo intermittent tests are very practical and have been considered the most valid approaches to evaluate endurance of football players (Bangsbo et al., 2008).

The Yo-Yo intermittent recovery level 1 (Yo-Yo IR1) and Yo-Yo intermittent endurance level 2 (Yo-Yo IE2) tests are the versions mostly used to assess endurance in the evaluation of youth football players (Castagna et al., 2006; Rampinini et al., 2010). Although the effort in football relies on aerobic and anaerobic metabolism, the repeated high-intensity exercise performed during Yo-Yo tests allows a sport-specific evaluation of players' physical capacity (Krustrup et al., 2003; Krustrup, Mohr, Nybo, et al., 2006). Moreover, it was observed that the Yo-Yo IR1 is a reliable test and a valid measure of the ability to perform HIR in football matches (Krustrup et al., 2003; Reilly, 2006), Thus, the Yo-Yo IR1 may be regarded as a useful test to assess game readiness and to guide training prescription in male youth football players (Castagna et al., 2009). Recent data has also suggested that the Yo-Yo IE2 test is a sensitive tool that relates to match performance, differentiating the intermittent exercise performance of youth players in various standards, stages of the season and playing positions (Bradley et al., 2011).

However, it has not yet been investigated in the same cohort of players whether the maximum aerobic power and the performance in Yo-Yo IR1 and Yo-Yo IE2 are important determinants of the physical match performance in youth football. Thus, the aims of the present study were (1) to analyse the activity profile of youth football players in various phases during match play, and (2) to examine the relationship between physical match performance and two popular intermittent-exercise field tests as well as maximal oxygen uptake.

Methods

Experimental approach to the problem

Data were collected during a 4-week period in the middle of a 9-month competitive season. Anthropometric measurements as well as laboratory and field tests took place in the first two weeks of the study period. The players performed an incremental laboratory treadmill test (to measure $\dot{V}O_{2max}$), and two field tests: the Yo-Yo IR1 and the Yo-Yo IE2. The laboratory and field tests were conducted in random order and were completed within a 2-week intermission period in the competitive schedule, officially imposed by the National Football Association. The following 2-week period was devoted to training and match assessments. Heart rate was monitored during two official matches, played 2 weeks apart as host team. Time–motion analysis was performed for the 10 outfield players of each of the three analysed teams.

Subjects

Thirty-nine regional-level youth football players from three different teams, competing in the first division of the U-17 Portuguese football league, were analysed in this study. Only outfield players were included. Their age, stature, mass, percentage of body fat and mean peak heart rate (HR) were (mean ± SD) 15.6 ± 1.4 years, 169.5 ± 7.1 cm, 61.5 ± 12.5 kg, 14.9% ± 4.1% and 197 ± 9 b·min^{-1}, respectively. During games, one player suffered an injury and eight players were substituted. Those players were not considered for further analyses. Therefore, the final sample included 30 players: fullbacks ($n = 7$), central defenders ($n = 7$), midfielders ($n = 8$) and forwards ($n = 8$). All players were interviewed to provide information concerning the number of years of football practice and hours of regular training per week. Players were regularly involved in football for 4.0 ± 2.6 years. Players and their parents provided informed consent, and ethical

consent was approved by the Scientific Committee of the Faculty of Sport of the University of Porto and by the club officials. All procedures were conducted according the declaration of Helsinki.

Match analysis

Each player was filmed and analysed in two consecutive matches (80-min duration) separated by 15 days. To avoid interferences of pitch dimensions, all the videotaped games were restricted to home-played matches and were filmed by the same group of researchers. Time–motion analysis was performed according to the procedures defined elsewhere (Castagna, D'Ottavio, & Abt, 2003; Mohr et al., 2003), and the mean data of the two matches was used for analysis. Each player was filmed close up during the entire match by digital video cameras (DCR-HC53E, Sony, Japan) positioned at the side of the field, at a height of about 15 m, and at a distance of 30–40 m from the touchline. The videotapes were later replayed on a monitor for computerising coding of the activity pattern. Match activities were determined according to Castagna et al. (2003): standing (St, speed from 0 to 0.4 $km \cdot h^{-1}$); walking (W, speed from 0.4 to 3.0 $km \cdot h^{-1}$); jogging (J, speed from 3.0 to 8.0 $km \cdot h^{-1}$); medium-intensity running (MIR, speed from 8.0 to 13.0 $km \cdot h^{-1}$); HIR (speed from 13.0 to 18.0 $km \cdot h^{-1}$); sprinting (Sp, speed faster than 18.0 $km \cdot h^{-1}$); and backwards running (BwR, speed from 5.0 to 15.0 $km \cdot h^{-1}$). The former activities were later divided into two locomotor categories: (1) low-intensity activities, encompassing standing, walking, jogging, medium-intensity running and backwards running; and (2) HIA, consisting of HIR, and sprinting. The frequency and duration of each activity category were recorded and the data presented for 13.3-, 40- and 80-min periods of the match (Mohr et al., 2003). The six 13.3-min intervals were chosen instead of the common 15-min periods (Mohr et al. 2003), because U-17 competitive matches have 80-min duration (adult football matches have 90-min duration). The distance covered for each activity within each time interval was determined as the product of the total time and mean speed for that activity. The total distance covered during the match was calculated as the sum of the distances covered during each type of activity. All the match recordings were analysed by an experienced observer. In a study by Krustrup and Bangsbo (2001), it was observed that the coefficients of variation for test–retest analysis were 1% for total distance covered, 2% for walking, 5% medium-intensity running, 3% for HIR and 3% for sprinting and backwards running. The players' locomotive style was analysed and validation tests were performed according to the predetermined locomotor categories as recommended (Krustrup et al., 2005; Mohr et al., 2003). The two halves of the match were analysed in a random order.

Heart rate measurements during the match

HR was recorded continuously during each match at 5-s intervals via short-range radio telemetry (Polar Team System™, Polar Electro, Kempele, Finland). To reduce HR recording errors, the players were asked to check their HR monitors before each match and at the half-time break of the match. Following each match, HR data was then downloaded to a computer using Polar Software (Polar Electro, Kempele, Finland).

Testing

Performance in prolonged intermittent exercise. The Yo-Yo IR1 and the Yo-Yo IE2 were performed before the videotaped matches, two weeks apart, in a random order. After a 10-min warm up including the first four running bouts of the test (Krustrup et al., 2003), the players repeated 2×20 m runs back and forth between the start and finish line at a progressively increasing speed, controlled by audio bleeps from a CD-ROM according to the guidelines of Bangsbo (1996). The test was terminated when the subjects failed twice to reach the starting line (objective evaluation) or the participant felt unable to complete another shuttle at dictated speed (subjective evaluation). The total distance covered during the Yo-Yo IR1 and the Yo-Yo IE2 was recorded and represented the test result. Heart rate was measured during the tests and recorded every 5 s using HR monitors. The individual maximum HR (HR_{max}) was determined as the highest value reached either in the Yo-Yo IR1, Yo-Yo IE2 and treadmill test or in the match.

Laboratory treadmill evaluation

Initially, anthropometric measurements were performed, including body height (fixed stadiometer, Holtain Ltd., UK), body weight and fat percentage (Tanita®, BC-418MA, USA). The laboratory treadmill test was performed starting with a warm up at speeds 6 and 8 $km \cdot h^{-1}$ in 2.5-min stages followed by an incremental maximal test. The maximal test began at a speed of 10 $km \cdot h^{-1}$, with a stepwise increase in speed of 1 $km \cdot h^{-1}$ every 60 s until exhaustion. After the maximal test, subjects ran at 5 $km \cdot h^{-1}$ for 5 min. Heart rate was recorded in 5-s intervals throughout the entire protocol using a Polar Vantage NV heart rate monitor (Polar Electro Oy, Kempele, Finland). Oxygen uptake was measured

during the entire test using a breath-by-breath gas analysis system ($K4b_2$, Cosmed, Rome, Italy). Before each testing session, the $K4b_2$ was calibrated according to the manufacturer guidelines. The variables selected for the analysis were maximal oxygen consumption ($\dot{V}O_{2max}$), peak HR, and speed attained at $\dot{V}O_{2max}$ ($v\dot{V}O_{2max}$). Two criteria were considered for $\dot{V}O_{2max}$ determination: (1) plateau in $\dot{V}O_2$ (an increase less than 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ despite an increase in running speed); and (2) respiratory exchange ratio (RER) greater than 1.10 (Howley, Bassett, & Welch, 1995).

Statistics

Results are presented as mean and standard deviation. Differences between the various phases of the game (e.g. 13.3-min periods) were tested using repeated-measures ANOVA. When significant interaction was detected, data were subsequently analysed using a Bonferroni' s*post hoc* test. Differences between the first and the second halves of the were calculated using a Student paired *t*-test. The correlation coefficients were determined using Pearson's product-moment test. The magnitude for correlation coefficients were considered as trivial ($r < 0.1$), small ($0.1 < r < 0.3$), moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($r > 0.9$) and perfect ($r = 1.0$), in accordance with Hopkins' definitions (Hopkins, 2010). Statistical significance was set at $P < 0.05$.

Results

Activity profile during match play

The total distance covered during the match was 6311 ± 948 (4435–8098) m, of which ~12% (759 ± 437, 374–2062 m) were performed at HIA. Players spent approximately 87% of total match duration in standing, walking and jogging, while HIA accounted for 3.1% (Table I). No differences between halves in the time spent in each movement category were found ($P > 0.05$).

The total distance covered during the first 13.3-min period of the match was 11%–29% higher than in the remaining 13.3-min periods ($P < 0.05$). Additionally, the distance covered during the last 13.3-min period of the match was lower than during the second and fourth periods ($P < 0.05$; Figure 1(a)). The distance covered in backwards running decreased by 31% and 37% in the last 13.3-min periods of the first and second halves, respectively, comparing with the first 13.3-min period of the game ($P < 0.05$; Figure 1(b)).

Although without statistical significance, the distance covered in HIA in 13.3-min periods tended to decrease throughout the game (first period, 160 ± 111 m; second period, 127 ± 82 m; third period, 125 ± 88 m; fourth period, 137 ± 81 m; fifth period, 109 ± 62 m; sixth period, 91 ± 49 m; $P = 0.058$). The peak distance covered with HIA in a 13.3-min period was 192 ± 97 m, which was 71% higher than the following 13.3-min periods (112 ± 84 m; $P < 0.001$; Figure 2). Seventy-five percent of the players had their most intense 13.3-min period in the first half of the game and 47% of the players had the most intense exercise period in the first 13.3-min period of the game. Moreover, 60% of the players had their least intense exercise period in the first half the game. The average distance covered in HIA during all the 13.3-min intervals was 129 ± 74 m, which was higher ($P = 0.002$) than in the 13.3-min period that followed the peak period (Figure 2).

Heart rate during match play

Mean HR during the match was 168 ± 12 bpm (range: 140–187). This value corresponded to 85% (69–91) of HR_{max}, which was 198 ± 9 bpm (176–213). Players spent $40\% \pm 11\%$ (14–67), $23\% \pm 9\%$ (5–38), and $10\% \pm 8\%$ (0–28) of the playing time with the HR between 80%–90%, 90%–95%, and >95% of the maximal HR, respectively.

Yo-Yo performances and $\dot{V}O_{2max}$

The performance of the Yo-Yo IR1 and IE2 were 1462 ± 356 (range: 720–2280) and 1171 ± 331 (640–1760) m, respectively. $\dot{V}O_{2max}$ was 61.8 ± 5.6

Table I. Activities performed and distances covered during the match by youth soccer players (mean ± SD)

	Frequency (*n*)	Duration (s)	Total time (%)	Distance covered (m)
St	154 ± 48	4.5 ± 1.1	14.4 ± 5.0	0 (0)
W	382 ± 73	6.7 ± 1.9	53.3 ± 8.3	2116 ± 482 (1269–3359)
J	441 ± 108	2.1 ± 0.4	19.8 ± 4.5	2025 ± 458 (1090–3095)
MIR	196 ± 70	1.6 ± 0.2	6.5 ± 2.0	1102 ± 371 (619–1794)
HIR	84 ± 50	1.3 ± 0.3	2.3 ± 1.2	529 ± 312 (215–1461)
Sp	29 ± 20	1.4 ± 0.4	0.8 ± 0.4	230 ± 135 (88–601)
BwR	87 ± 54	1.5 ± 0.4	3.0 ± 1.8	309 ± 205 (12–776)

St: standing; W: walking; J: jogging; MIR: medium-intensity running; HIR: high-intensity running; Sp: sprinting; BwR: backwards running.

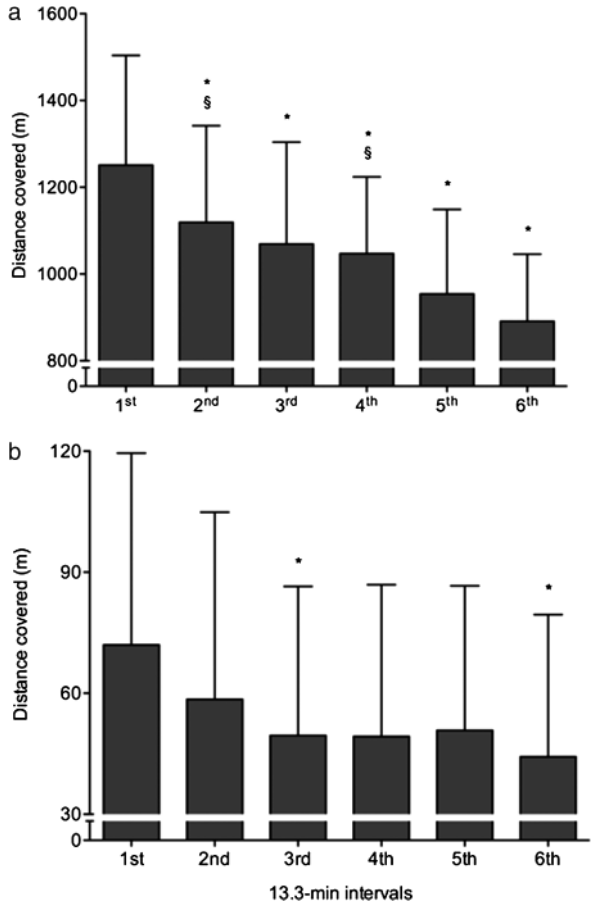

Figure 1. Total distance (a) and backwards running (b) covered in six 13.3-min intervals during the match (80-min duration). means ± SD are presented.
*Significantly different from the first 13.3-min interval of the match ($P < 0.05$). §Significantly different from the last 13.3-min interval ($P < 0.05$).

(45.6–72.3) ml·min^{-1}·kg^{-1}. No correlations were observed between $\dot{V}O_{2max}$ and the distance covered in the Yo-Yo tests ($r = 0.25$–0.63; $P > 0.05$). No significant differences were observed in peak HR during the Yo-Yo IR1 and IE2, the incremental treadmill test and the match (196 ± 10; 198 ± 9; 191 ± 11; and 197 ± 9 bpm; respectively; $P > 0.05$).Midfielders performed better in the Yo-Yo IE2 than central defenders and forwards ($P < 0.05$; Table II), whereas, no position-related differences were observed for Yo-Yo IR1 performance and the $\dot{V}O_{2max}$ ($P > 0.05$).

Relationship between physical capacity and match performance

The coefficients of correlation between the distance covered in the Yo-Yo tests and treadmill test variables with match activities, as well as HR of the players during the match are presented in Table III.

Briefly, the Yo-Yo IR1 and the Yo-Yo IE2 tests showed significant moderate to large correlations

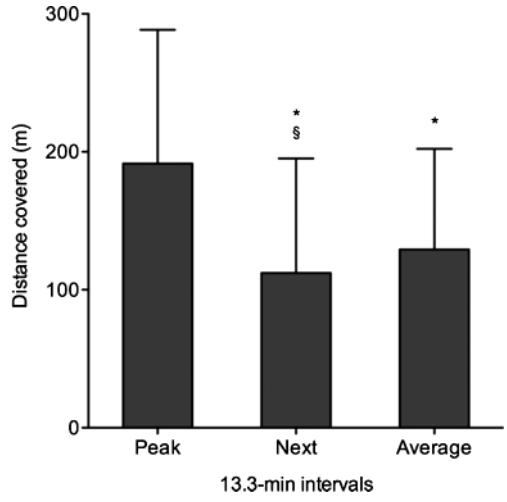

Figure 2. Distance covered in high-intensity activity (HIA) in the 13.3-min interval with more HIA (Peak 13.3-min), in the 13.3-min interval that followed the peak 13.3-min (next 13.3-min) and the average values of all the 13.3-min intervals (average 13.3-min) of the match. means ± SD are presented.
*Significantly different from the Peak 13.3-min interval ($P < 0.001$). §Significantly different from the Average 13.3-min interval ($P < 0.01$).

with the time spent in HIR and in HIA during the match ($P < 0.05$; Figure 3(a)). Both tests also showed moderate to large correlations with the mean HR during games ($P < 0.05$; Figure 3(b)). Additionally, the Yo-Yo IR1 presented large correlations with the time spent in sprinting during the match ($P = 0.002$; Figure 3(c)) and during the last 13.3-min period of the game ($P = 0.022$; Table III).

No significant correlations were found between the distance covered in the Yo-Yo tests and the analysed measures of aerobic power ($P > 0.05$). From all incremental treadmill test variables, only v$\dot{V}O_{2max}$ showed moderate correlation time spent in HIR, as well as with mean HR and the time spent >95% HR_{max} during games ($P < 0.05$; Table III). No further correlation was observed between the treadmill test variables and the activity profile during the match ($P > 0.05$).

Discussion

This study showed that the HRs were elevated and that the total distance covered and the amount of backwards running decreased significantly towards the end of youth football matches. Yo-Yo IR1 and Yo-Yo IE2 performances were associated with the time spent in HIA during the match. Additionally, the distance covered in the Yo-Yo IR1 was associated with the time spent in sprinting during the game and towards the end of the match. In contrast, $\dot{V}O_{2max}$ was not correlated to the activity profile during the match or to the Yo-Yo test performances.

Table II. Yo-Yo IR1 and Yo-Yo IE2 performance, and $\dot{V}O_{2max}$ attained during the incremental treadmill test (mean ± SD), as well as results of ANOVA testing the effects of field position on Yo-Yo tests and $\dot{V}O_{2max}$

	Position					Effect of position		
	FB ($n = 7$)	CD ($n = 8$)	MF ($n = 8$)	FW ($n = 7$)	Total ($n = 30$)	F	P	η^2
Yo-Yo IR1 (m)	1496 ± 335	1253 ± 231	1482 ± 444	1537 ± 290	1462 ± 356	0.80	0.501	0.06
Yo-Yo IE2 (m)	1130 ± 300	980 ± 311	1143 ± 274*	1020 ± 276	1171 ± 331	4.93	0.006	0.32
$\dot{v}o_{2max}$ (ml·min^{-1}·kg^{-1})	62.4 ± 3.8	60.3 ± 9.4	62.6 ± 6.8	61.8 ± 2.8	61.8 ± 5.6	0.31	0.816	0.03

FB: fullback; CD: central defender; MF: midfielder; FW: forward.
*Significantly different from CD and FW ($P < 0.05$).

As observed in senior elite and non-elite players (Bangsbo, Norregaard, & Thorso, 1991; Mohr et al., 2003), it was found that the average HR during games was ~85% of individual HR_{max}, and that the HR was at 90%–95%, and >95% of HR_{max} for 23%, and 10% of the playing time, respectively. These results show that youth football matches impose high demands on the cardiovascular system (Impellizzeri et al., 2006). At the same time, ~80% of match time was spent in low and moderate intensity activities revealing that in the global picture of U-17 match physical effort is similar to what has been observed in adult players.

The distance covered in the last 13.3-period of the match was lower than in the correspondent first, second and fourth and periods. Moreover, the distance covered in backwards running decreased significantly in last 13.3-min period of the first and second halves. Such changes might be attributed to the player's inability to cope with match tempo in the first periods of the match. A marked reduction in total running distance, HIA and backwards and sideways running towards the end of competitive games has also been observed for adult elite players and match officials (Ekblom, 1986; Mohr et al., 2003). Interestingly, backwards movements were affected in the last periods of the first and second halves. Backwards movements are sometimes preferable during match play (e.g. when a defender is facing the ball while marking the opponent), but previous studies showed that, compared with forward movements, unorthodox movements, such as sideways and backwards running, present higher energetic demand (Reilly & Bowen, 1984). Thus, it could be suggested that, as the game progresses and fatigue becomes more pronounced, players restraint themselves to perform movements with higher energetic cost, in special, the ones accomplished for positional adjustments in the field during the match.

The distance covered with HIA after the peak 13.3-min of HIA was lower than in the remaining intervals of the match. Similar results have been described in adult soccer players, when results were analysed in 5-min periods (Mohr et al., 2003). It was hypothesised that players could experience temporary fatigue in some periods of the match after being involved in peak periods of high-intensity exercise. Interestingly, 75% of the players had their most intense 13.3-min period in the first half of the game and 60% of the players had the least intense 13.3-min interval in the first half of the game. Altogether, these results suggest that players might have experienced a pronounced reduction in exercise intensity as a response to temporary fatigue after the most intense periods of the first half of the match.

Both Yo-Yo tests were associated with the time spent in HIR and the mean HR during the match. Positive correlations between performance in the

Table III. Coefficients of correlation between the distances covered in the Yo-Yo tests (Yo-Yo IR1 and Yo-Yo IE2) and the incremental treadmill test variables, and the locomotor activities and heart rate during matches of U-17soccer players ($n = 30$)

	Yo-Yo IR1	Yo-Yo IE2	$\dot{V}O_{2max}$	v$\dot{V}O_{2max}$
HIR (distance, m)	$r = 0.56$	$r = 0.45$	$r = 0.00$	$r = 0.45$
	$P = 0.010$	$P = 0.030$	$P = 0.996$	$P = 0.036$
Sprinting (distance, m)	$r = 0.63$	$r = 0.29$	$r = 0.15$	$r = 0.13$
	$P = 0.002$	$P = 0.320$	$P = 0.496$	$P = 0.559$
HIA (distance, m)	$r = 0.56$	$r = 0.57$	$r = 0.04$	$r = 0.39$
	$P = 0.015$	$P = 0.029$	$P = 0.875$	$P = 0.072$
Time sprinting in the last 13.3 min (%)	$r = 0.63$	$r = 0.12$	$r = 0.14$	$r = 0.06$
	$P = 0.022$	$P = 0.607$	$P = 0.552$	$P = 0.798$
Mean HR (% HR_{max})	$r = 0.61$	$r = 0.45$	$r = -0.13$	$r = 0.49$
	$P = 0.004$	$P = 0.046$	$P = 0.540$	$P = 0.017$
Time > 95% HR_{max} (%)	$r = 0.37$	$r = 0.05$	$r = 0.25$	$r = 0.44$
	$P = 0.106$	$P = 0.807$	$P = 0.253$	$P = 0.035$

v$\dot{V}O_{2max}$: maximal speed at $\dot{V}O_{2max}$; HIR: high-intensity running; HIA: high-intensity activity (HIR + Sprinting).

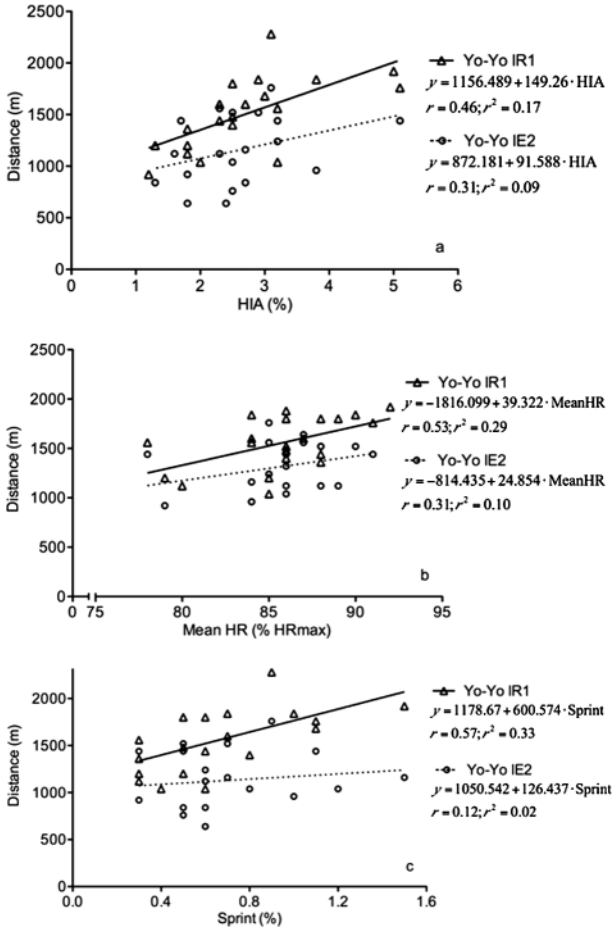

Figure 3. Individual relationships between the percentage of time spent with high-intensity activity (HIA) (a), the mean HR (presented as% HR_{max}) (b) and the percentage of time spent with sprinting (c) during the match, and the distance covered in the Yo-Yo IR1 and Yo-Yo IE2.

Yo-Yo-IR1 (Castagna et al., 2009, 2010) and the Yo-Yo IE2 (Bradley et al., 2011), and the amount of HIA performed in the match by youth football players have been described. In fact, HIA was suggested to be a precise measure of physical performance during a football game (Bangsbo et al., 1991; Ekblom, 1986; Krustrup et al., 2003). However, only the Yo-Yo IR1 was significantly associated with the time spent with sprinting during the game. Altogether, these results suggest that Yo-Yo IR1 is a better predictor of the ability to perform maximal intensity exercise during the match than Yo-Yo IE2. Krustrup et al. (2003) analysed the physiological response of the Yo-Yo IR1 test in elite football players and observed that during this version of the Yo-Yo assessment muscle lactate increased eightfold and muscle creatine phosphate and glycogen decreased by 51% and 23%, respectively. The authors concluded that during the Yo-Yo IR1 the anaerobic energy system was highly taxed. Overall, it seems that the Yo-Yo assessments' performance, especially the Yo-Yo IR1 version, is a more sensitive measure for variations in match physical performance than $\dot{V}O_{2max}$. This is also supported by the finding that top-class football referees improved their Yo-Yo IR1 test performance by 31% and the amount of HIR during competitive matches by 23% after 8 weeks of intense intermittent exercise training, with a negligible change in $\dot{V}O_{2max}$ (Krustrup & Bangsbo, 2001).

None of the physical match performance variables was associated with $\dot{V}O_{2max}$. In contrast with these results, significant positive correlations were observed between $\dot{V}O_{2max}$ of female elite football players and the amount of HIR during the match and in the last 15 min of each half of the match (Krustrup et al., 2005). These results suggest that physical performance of young football players during the match is relatively independent on the player's aerobic capacity. Nevertheless, in the present study, the amount of HIR, as well as the mean HR (as% HR_{max}) and the time spent above 95% HR_{max} during the match, were related with maximal speed at $\dot{V}O_{2max}$. Previous studies with top-level male football players have found significant correlations between peak speeds reached during an incremental field test and total distance covered, as well as the amount of high-intense exercise during games (Rampinini et al., 2007). These results suggest that, despite the ability to cover greater distances at high running speeds during a match that depends on aerobic fitness, other aerobic-dependent factors than $\dot{V}O_{2max}$ (e.g. ability to recover from high-intensity intermittent exercise, peak running speed during incremental tests) can be used to assess specific physiological components of football performance and to prescribe individualised physical training for football players (Rampinini et al. 2007).

Contrary to previous studies with U-13, U-14 and U-15 football players that did not find significant differences between positions in the distance covered in the Yo-Yo tests (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004; Wong, Chamari, Dellal, & Wisloff, 2009), in the present study midfield players performed better in the Yo-Yo IE2 than central defenders and forwards. In opposition to the aforementioned studies, we did not consider all the defensive players in the same positional group (i.e. defenders), but divided them in fullbacks and central defenders. Also, Portuguese youth teams usually play in 4:3:3, with no fixed positions for forward players. During games, elite central defenders and central forwards perform less maximal work than fullbacks and midfielders (Di Salvo et al., 2007; Mohr et al., 2003). Hence, a lower ability to perform intermittent exercise is expected for the corresponding central team formations. High match-to-match variability in performance characteristics has been observed for

elite football players, and therefore this inherent variability means that research requires large sample sizes in order to detect real systematic changes in performance characteristics (Gregson, Drust, Atkinson, & Salvo, 2010). In the present study, the sample size is statistically too small to allow match-performance comparisons between positional roles. Therefore, further studies are required to better understand the influence of different tactical systems in the position-specific physical demands of match play.

Conclusion

The present study showed that the Yo-Yo tests performance correlated with the amount of HIA performed in games. Moreover, as observed in elite male players (Krustrup et al., 2003), this study did not reveal any correlation between maximal oxygen uptake and match performance. Altogether, the results of the present study provide evidence that the performance on the Yo-Yo IR1 and Yo-Yo IE2 tests are good predictors of high-intensity activity throughout youth male football games. Nevertheless, the Yo-Yo IR1 test could give a better indication of the ability to perform maximal exercise during a match.

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