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The peak velocity derived from the Carminatti Test is related to physical match performance in young soccer players

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ABSTRACT

The aim of this study was to examine the relationship between the peak velocity derived from the Carminatti Test (T-CAR) ($PV_{T\text{-}CAR}$) and physical match performance in young soccer players. Thirty-three youth soccer players were recruited from 2 non-professional clubs. Friendly matches and small-sided game were performed. Physical match demands were assessed using Global Positioning System (GPS) technology. On a separate occasion, the players were submitted to the T-CAR. Players were categorised into 3 groups based on their T-CAR performance: Low ($PV_{T\text{-}CAR} \leq$ P33), Intermediate (P33 > $PV_{T\text{-}CAR}$ < P66) and High ($PV_{T\text{-}CAR} \geq$ P66). The $PV_{T\text{-}CAR}$ (15.5 ± 0.7 km·h^{-1}) was significantly related to high-intensity activities (HIA; r = 0.78, P < 0.001), high-intensity running (HIR; r = 0.66, P < 0.001), sprinting (r = 0.62, P < 0.001) and total distance (TD) covered (r = 0.47, P < 0.01) during friendly matches. The $PV_{T\text{-}CAR}$ was strongly correlated with the amount of HIA (r = 0.81, P < 0.001), HIR (r = 0.85, P < 0.001) and TD covered (r = 0.81, P < 0.001) during small-sided game. No significant correlation was observed between the $PV_{T\text{-}CAR}$ and distance of sprinting (r = 0.49, P = 0.067) during small-side game. Furthermore, players in the High group covered significantly more TD (10%) and did more HIA (42%), sprinting (31%) and HIR (25%) during friendly matches compared to the players classified as having Low performance on the T-CAR. These differences still remained after adjusting for chronological age (CA), maturity and body size. In conclusion, the current study gives empirical support to the ecological and construct validity of this novel field test (T-CAR) as an indicator of match-related physical performance in young soccer players during pubertal years.

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Intermittent exercise; team sports; aerobic fitness; match analysis; youth athletes

Introduction

Soccer includes high-intensity activities (HIA) interspersed with periods of low-intensity effort (Castagna, Manzi, Impellizzeri, Weston, & Barbero Alvarez, 2010). Time–motion analyses have indicated that soccer players aged 13–16 years cover 6–8 km during an official match (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Castagna et al., 2010; Rebelo, Brito, Seabra, Oliveira, & Krustrup, 2014), of which around 12–16% are performed at HIA (Castagna, Impellizzeri, Cecchini, Rampinini, & Barbero Alvarez, 2009; Rebelo et al., 2014). Moreover, players significantly reduce their physical performance in the second half of each game (Castagna et al., 2010; Rebelo et al., 2014), sustaining less time at exercise intensities above 81% of maximal heart rate (HRmax) (Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013). These data highlight the importance of intermittent endurance running capacity, which is a relevant physical component related to the ability to perform repeated high-intensity intermittent efforts during competitive matches (Castagna et al., 2009, 2010; Rebelo et al., 2014). Longitudinal studies in soccer players have reported that the development of intermittent endurance running capacity during the adolescence period is positively influenced by soccer-specific training in addition to increasing chronological age (CA) and maturity (Roescher, Elferink-Gemser, Huijgen, & Visscher, 2010; Valente-Dos-Santos et al., 2012).

Field tests have been proposed as a viable and sustainable alternative to laboratory tests (Svensson & Drust, 2005). Currently, several field tests designed to evaluate the intermittent endurance running capacity in youth soccer players are available (Da Silva et al., 2011; Krustrup et al., 2003). These tests have been used in professional practice to structure short- and long-term training programmes and to assist in the talent identification and selection process (Roescher et al., 2010; Svensson & Drust, 2005; Valente-Dos-Santos et al., 2012). The majority of these field tests are positively associated with criterion physiological measures of aerobic fitness (e.g., VO_2peak) (Castagna, Impellizzeri, Rampinini, D'Ottavio, & Manzi, 2008; Da Silva et al., 2011; Teixeira et al., 2014). However, it has been demonstrated that VO_2peak and

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physical match performance are poorly correlated in youth soccer players (Rebelo et al., 2014). With this in mind, further studies examining the association between match running performance and field test output are required.

The Yo-Yo Intermittent Recovery Test Level 1 (Yo-Yo IR1) and the Multistage Fitness Test (MSFT) are the 2 most widely used tests to evaluate intermittent endurance capacity in team sports research (Castagna et al., 2010; Krustrup et al., 2003). Previous studies have shown a significant correlation between the results of the Yo-Yo IR1 and the MSFT and the amount of HIA during a competitive match (Castagna et al., 2009, 2010).

However, in terms of practical relevance to planning aerobic training interventions, the Yo-Yo IR1 and the MSFT both seem to underestimate the maximal aerobic speed (MAS) in team sports players (Castagna et al., 2008; Dupont et al., 2010; Williford, Scharff-Olson, Duey, Pugh, & Barksdale, 1999). Thus, an additional aerobic field testing protocol, labelled as the Carminatti Test (T-CAR), has been proposed (Da Silva et al., 2011). It uses the peak velocity reached at the end of the test ($PV_{T\text{-}CAR}$) to estimate the MAS and to individualise running distance during interval training sessions in soccer players (Da Silva et al., 2011; Teixeira et al., 2014). The test has acceptable relative and absolute reliability in soccer players (Da Silva et al., 2011; Teixeira et al., 2014). Furthermore, previous studies have described the concurrent validity of the T-CAR in adult and youth soccer players, reporting large to very large correlations between the $PV_{T\text{-}CAR}$ and key aerobic fitness parameters determined in laboratory tests (Da Silva et al., 2011; Teixeira et al., 2014). From a practical perspective, a recent investigation also showed that the $PV_{T\text{-}CAR}$ appears to be independent of maturity-related variations during puberty in soccer players aged 10–15 years (Teixeira et al., 2015). These findings are potentially relevant to coaches and conditioning professionals involved in the selection and development of youth soccer players; in particular, to prevent the deselection of late maturing players.

Despite the growing interest and recent investigations that promote T-CAR as a valuable tool for the assessment of intermittent endurance running capacity under field conditions in soccer players (Da Silva et al., 2011; Teixeira et al., 2014), no study to date has examined the ecological validity of this novel test in youth soccer players during adolescence. Given that some of the most important soccer action (e.g., goals) generally occur following HIA (Faude, Koch, & Meyer, 2012), it becomes essential for training prescription and fitness assessment to understand the direct association between the $PV_{T\text{-}CAR}$ and match performance. Information about this association would be of practical interest because ecological validity is considered to be an important property of a soccer-specific field test (Impellizzeri & Marcora, 2009). In addition, it has not yet been investigated in youth soccer whether a better performance on the T-CAR also translates into a greater distance covered at HIA during the small-sided game format (7v7), which is commonly used in daily training sessions (Hill-Haas, Coutts, Rowsell, & Dawson, 2008).

Therefore, the purpose of the current study was to examine the relationship between T-CAR performance and physical match performance in male youth soccer players aged 13.5–15.9 years using friendly matches (11v11) and the small-sided game format (7v7). As a working hypothesis, the existence of a significant association between the $PV_{T\text{-}CAR}$ and physical match demands during both 11v11 and 7v7 games in youth soccer players was assumed.

Methods

This study was performed according to the Declaration of Helsinki, and experimental protocol was approved by the Local Human Research Ethics Committee. The clubs and parents or legal guardians provided informed written consent, and the players provided assent. Participants were informed about the nature of the study; participation was voluntary and players could withdraw at any time.

Participants

This cross-sectional sample included 33 male youth soccer players aged 13.5–15.9 years old who were recruited from 2 non-professional clubs competing at a regional level. Only outfield players were considered in the current study. The distribution of the players by playing position was as follows: 7 central defenders, 6 external defenders, 5 central midfielders, 7 external midfielders and 8 forwards. The position of each outfield player was obtained by interview and confirmed with the coach. Players performed 3 regular training sessions per week (about 90–120 min per session) and participated in weekly competitive matches, usually on Saturdays. At the time of study, training sessions consisted mainly of technical and tactical skill development (80% of the training time). Physical conditioning was performed 1 time per week and was focused on drills of coordination, speed, repeated sprint ability and endurance performance development.

Experimental procedures

Ecological validity usually refers to the extent to which the inherent characteristics of the test reflect the conditions experienced in real-world settings (Currell & Jeukendrup, 2008; Impellizzeri & Marcora, 2009). To verify the ecological validity of this novel field test, the association between the $PV_{T\text{-}CAR}$ derived from the T-CAR and physical match performance during both 11v11 and 7v7 games was examined using a descriptive correlation design. Construct validity refers to the degree in which a protocol measures a hypothetical construct (Currell & Jeukendrup, 2008). In order to investigate the construct validity, match running performance variables were compared between adolescent soccer players of different performance levels on the T-CAR. The players were categorised into 3 groups based on their T-CAR performance using percentile values: Low ($PV_{T\text{-}CAR} \leq P33$), Intermediate ($P33 > PV_{T\text{-}CAR} < P66$) and High ($PV_{T\text{-}CAR} \geq P66$). The values for P33 and P66 were 15.12 and 15.60 $km \cdot h^{-1}$, respectively.

The entire study period was conducted within a 3-week period. Anthropometric and biological maturity measurements as well as the field test took place in the first week of the study period. The following 2-week period was devoted to friendly matches (11v11) and the small-sided game format (7v7), as illustrated in Figure 1. Intermittent endurance running capacity

Figure 1. The experimental design of the current study.

and match running performance were assessed using the T-CAR and Global Positioning System (GPS) technology, respectively.

Anthropometry and biological maturity

Anthropometry was assessed by a single, experienced individual following standard procedures (Lohmann, Roche, & Martorell, 1988). Body mass was measured to the nearest 0.1 kg using a calibrated scale (Soehnle, Murrhardt, Germany). Stature and sitting height were measured to the nearest 0.1 cm with a stadiometer (Sanny, American Medical do Brazil, São Paulo, Brazil) and sitting height table (Harpenden model 98.607, Holtain Ltd., Crosswell, UK), respectively. Leg length (subischial) was estimated as stature minus sitting height.

Age at peak height velocity (APHV) was estimated with the maturity offset protocol (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). This technique estimates time before or after peak height velocity (PHV) from CA, stature, body mass, sitting height and estimated leg length. Negative offset values indicated time before PHV and positive values indicated time after PHV. Negative offset values were added to and positive offset values were subtracted from CA to estimate APHV.

Match analysis

In this study, the activity profile of the players during matches was assessed using GPS technology with an operational sampling frequency of 10 Hz (K-Gps, K-Sport, Montellabate, Italy). During matches, all players wore the same GPS devices (Buchheit et al., 2010), inserted into a purpose-built backpack and positioned on the upper part of their backs. In the weeks prior to the study, the players were familiarised with the use of these devices.

Research has suggested that, compared with other methods of analysis, GPS devices tend to underestimate the distance covered at higher speeds (Randers et al., 2010). However, using a higher sampling frequency seems to increase the accuracy of the information provided by these devices (Rampinini et al., 2015). With this approach, the reliability, accuracy and validity of the devices used in this study (with a sampling frequency of 10 Hz) can produce better results (Castellano, Casamichana, Calleja-Gonzalez, Román, & Ostojic, 2011) than those obtained in previous studies (Buchheit et al., 2010), which used a sampling frequency of 1 and 5 Hz. The GPS system was tested for validity and reliability by the study authors before the commencement of the study, and it provided results comparable to the GPS systems currently used for match analyses in soccer (Castellano et al., 2011).

Match activities were assessed from 2 consecutive friendly matches (11v11) on the same natural grass soccer pitch. The matches were separated by at least 72 h. Pitch dimensions during friendly matches were 90 m × 45 m. The 11v11 matches were played in 2 halves lasting 35 min (10 min of rest intervals). The relative playing area to each player was approximately 210 m^2, as was the length:width ratio of the pitch (2:1). During the friendly matches, only data from players who participated in the full game were retained.

Similarly, the activity profile of each player during a small-sided game format (7v7 with goalkeepers) was also examined, monitoring 2 training sessions in the last week of the study period. The 7v7 games were played in a single 10 min period. Pitch dimensions during 7v7 games was 70 × 35 m in order to maintain the same relative playing area to each player and length:width ratio of the pitch (as per the 11v11). The 7v7 games included only 21 players, because the other 12 players who participated in the friendly matches (11v11) had travelled to take part in a competition performed outside the region where the study was conducted.

Match activities during friendly matches (11v11) and small-sided game formats (7v7) considered in the present study were determined according to Castagna et al. (Castagna et al., 2009, 2010): 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 $km{\cdot}h^{-1}$); high-intensity running (HIR, speed from 13.0 to 18.0 $km{\cdot}h^{-1}$); sprinting (SPR, speed > 18.0 $km{\cdot}h^{-1}$); and high-intensity activity (HIA: HIR + SPR).

The intraclass correlation coefficient (ICC) values (relative reliability) for the activity categories considered in the current study ranged from 0.88 to 0.95. Similar values have been reported in a previous study with youth soccer players (Castagna et al., 2009).

Heart rate

Heart rates (HR) were monitored using a long-range telemetry system (Polar T2 system, Polar Oy, Kempele, Finland) every 5 s during the matches and during the protocol. Peak HR reached at the end of the test (T-CAR) was considered as representative of individual HRmax (Da Silva et al., 2011).

Carminatti test

The test consists of intermittent shuttle runs of 12 s until volitional exhaustion, performed between 2 lines set at progressive distances, with a 6-s recovery between each run and a total stage time of 90 s. The test has a starting velocity of 9 $km{\cdot}h^{-1}$ over a running distance of 30 m (15 m out and back).

The length in a single direction is increased progressively by 1 m at every level. Each stage consists of 5 repetitions with a 6-s walking period between 2 lines set 2.5 m from the starting line (Da Silva et al., 2011; Teixeira et al., 2014). A total of 8–10 players were evaluated simultaneously with the running pace dictated by a pre-recorded audio system (Da Silva et al., 2011; Teixeira et al., 2014). The test ended when participants failed to follow the audio cues on the front line for 2 successive repetitions (using objective criteria applied by observers). The $PV_{T\text{-}CAR}$ was calculated from the distance of the last set completed by the player divided by the time to complete the full set of repetitions. In the case of an incomplete set, peak velocity was interpolated using the equation: PV = ***v*** + (ns/10)*0.6, where "***v***" is the velocity of the last fully completed stage and "ns" is the number of repetitions completed in the partially completed stage. Reproducibility of the $PV_{T\text{-}CAR}$ has been reported previously, with replicate tests within a period of 1 week among 34 youth players aged 10.2–13.0 years. The ICC and measurement error expressed as a coefficient of variation for $PV_{T\text{-}CAR}$ were, respectively, 0.89 and 2.30% (0.3 $km \cdot h^{-1}$) (Teixeira et al., 2014).

Statistical analyses

Results are presented as mean ± SD. Normality was checked using the Shapiro–Wilk test and visual inspection. Pearson's product–moment correlations between the $PV_{T\text{-}CAR}$ and match running performance were calculated first as zero order and then as partial correlations adjusting first for CA and APHV and then for body size (body mass and stature). The magnitude of correlations was qualitatively assessed as follows: trivial ($r < 0.1$), small ($0.1 > r < 0.3$), moderate ($0.3 > r < 0.5$), large ($0.5 > r < 0.7$), very large ($0.7 > r < 0.9$) and nearly perfect ($r > 0.9$). Match activities were also compared among players categorised in the 3 $PV_{T\text{-}CAR}$ groups using one-way analysis of variance (ANOVA) and analysis of covariance (ANCOVA; with CA, estimated APHV and body size as covariates). Results derived from ANCOVA are reported as adjusted mean ± standard error. The magnitude of the differences was assessed using standardised mean differences (Cohen effect size, ES) which were interpreted as trivial (≤ 0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), very large (2.0–4.0) and nearly perfect (> 4.0) (Batterham & Hopkins, 2006). Statistical significance was set at $P < 0.05$. Analyses were performed using SPSS (SPSS 17.0 version, Chicago, Illinois, USA).

Results

Descriptive statistics for the total sample are summarised in Table 1. CAs ranged from 13.5 to 15.9 years, while estimated APHV ranged from 12.3 to 14.7 years. With the exception of 7 players, all maturity offset values were positive, indicating that the sample was beyond the age of maximum growth rate in stature during the adolescent growth spurt.

The relationship between the $PV_{T\text{-}CAR}$ and match running performance during 11v11 and 7v7 games are presented in Table 2. The $PV_{T\text{-}CAR}$ (15.5 ± 0.7 $km \cdot h^{-1}$) was positively associated with the amount of HIA, match HIR, sprinting and TD covered, with correlation coefficients ranging from moderate to very large. During 7v7 games, the $PV_{T\text{-}CAR}$ was also strongly correlated with the TD and the distance covered at HIA and HIR ($0.75 > r > 0.85$; $P < 0.01$). However, no significant correlations were found between the $PV_{T\text{-}CAR}$ and the distance of sprinting during 7v7 games. The correlation coefficients remained unchanged after controlling for CA, APHV and body size, showing that these covariates do not appear to influence the relationship between $PV_{T\text{-}CAR}$ and match running performance during 11v11 and 7v7 games.

Table 1. Descriptive statistics for the total sample (n = 33).

		Range		Shapiro–Wilk	
	Mean ± SD	Minimum	Maximum	Value	P
Chronological age (years)	14.5 ± 0.6	13.5	15.9	0.96	0.31
Years from PHV (years)	0.65 ± 0.76	−0.70	2.50	0.95	0.16
APHV (years)	13.8 ± 0.6	12.3	14.7	0.96	0.37
Body mass (kg)	61.5 ± 9.5	46.3	88.0	0.97	0.41
Stature (cm)	168.0 ± 7.4	153.0	182.5	0.98	0.84
Sitting height (cm)	86.9 ± 4.2	80.0	95.3	0.97	0.47
Estimated leg length (cm)	81.1 ± 4.5	72.0	88.5	0.96	0.35
$PV_{T\text{-}CAR}$ ($km \cdot h^{-1}$)	15.5 ± 0.7	13.7	16.9	0.96	0.26

PHV, peak height velocity; APHV, estimated age at PHV; $PV_{T\text{-}CAR}$, peak velocity derived from the Carminatti Test.

Table 2. Bivariate and partial correlation between the $PV_{T\text{-}CAR}$ and match running performance during 11v11 and 7v7 games, controlling for chronological age (CA), estimated age at peak height velocity (APHV) and body size descriptors.

		Partial correlation	
11v11 games (n = 33)	Bivariate correlation	CA, APHV	Body mass, stature
$PV_{T\text{-}CAR}$ vs. TD	0.47*	0.44*	0.51*
$PV_{T\text{-}CAR}$ vs. HIR	0.66#	0.69#	0.73#
$PV_{T\text{-}CAR}$ vs. Sprinting	0.62#	0.59#	0.52*
$PV_{T\text{-}CAR}$ vs. HIA	0.78#	0.76#	0.77#
7v7 games (n = 21)			
$PV_{T\text{-}CAR}$ vs. TD	0.81#	0.82#	0.77*
$PV_{T\text{-}CAR}$ vs. HIR	0.85#	0.80#	0.84#
$PV_{T\text{-}CAR}$ vs. Sprinting	0.49	0.38	0.36
$PV_{T\text{-}CAR}$ vs. HIA	0.81#	0.75*	0.76*

$PV_{T\text{-}CAR}$: peak velocity derived from the T-CAR; TD: total distance; HIR: high-intensity running; HIA: high-intensity activities.
*$P < 0.01$.
#$P < 0.001$.

Comparisons among players with contrasting performance on the T-CAR for TD covered, HIR, sprinting and HIA during 11v11 games are illustrated in Figure 2. Players in the High group had higher mean values for TD covered ($F_{2,27}$ = 4.468; P = 0.021; ES = 1.46) and HIR ($F_{2,27}$ = 6.417; P = 0.005; ES = 1.65) compared to players classified in the Low group (Figure 2(a,b)). Furthermore, players in the High group covered, on average, 42% and 23–31% more distance at sprinting (ES = 1.71 and 1.42) and HIA (ES = 1.78 and 1.97), respectively, than those players classified as having Intermediate and Low performance on the T-CAR (Figure 2(c,d)). These differences among players of contrasting performance on the T-CAR for TD covered, HIR, sprinting and HIA still persisted when CA, APHV and body size were statistically controlled by ANCOVA (Table 3). The magnitude of effect sizes ranged from moderate to very large for comparisons between the Low and High groups, from trivial to large between the Low and Intermediate groups, and moderate to large when a comparison was made between the Intermediate and High groups (Table 3).

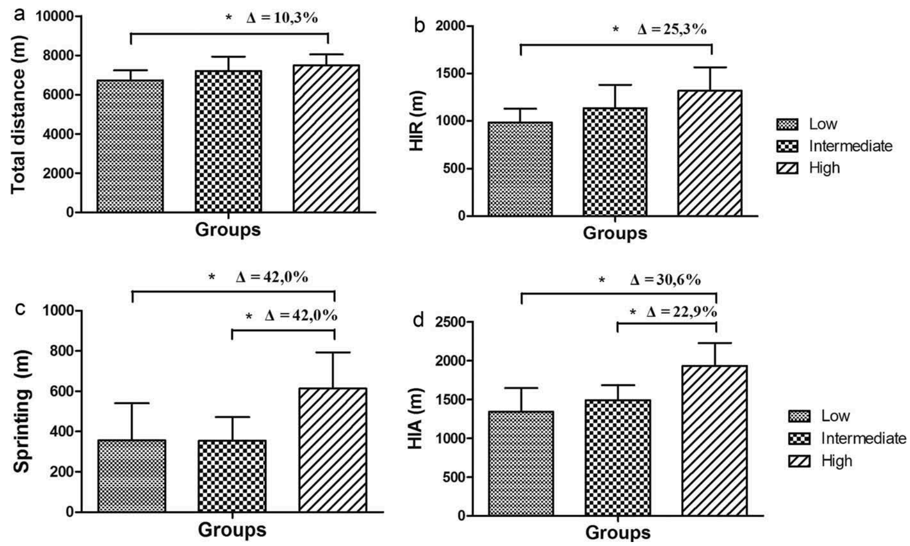

Figure 2. Physical match performance variables among youth soccer players categorised as Low (n = 10), Intermediate (n = 9) and High (n = 13) performance on the T-CAR. Data are presented as mean ± SD.

Table 3. Physical match performance variables during 11v11 games (mean adjusted ± standard error) among players with contrasting performance on the T-CAR, results of univariate ANCOVA (controlling for CA, estimated APHV and body size) with magnitude of effect size.

	Low (1) (n = 11)	Intermediate (2) (n = 9)	High (3) (n = 13)	F	P	ES 1 vs 2	ES 1 vs 3	ES 2 vs 3
TD (m)	6549 ± 151[a]	7177 ± 157[b]	7713 ± 160[bc]	12.0	<0.001	1.29 (large)	2.31 (very large)	1.09 (moderate)
HIR (m)	929 ± 72[a]	1117 ± 62[a]	1397 ± 64[b]	12.1	<0.001	0.96 (moderate)	2.31 (very large)	1.42 (large)
Sprinting (m)	390 ± 56[ab]	360 ± 58[b]	569 ± 59[ac]	3.3	0.050	0.16 (trivial)	0.96 (moderate)	1.15 (moderate)
HIA (m)	1319 ± 93[a]	1478 ± 97[a]	1967 ± 99[b]	10.4	0.001	0.52 (small)	2.07 (very large)	1.61 (large)

CA, chronological age; APHV, age at peak height velocity; TD, total distance; HIR, high-intensity running; HIA, high-intensity activities.
Values in the same row having the same superscript are not significantly different (P > 0.05).

Discussion

This study examined the validity of the T-CAR test in young male soccer players. The main original finding demonstrated a significant moderate to very large association between the $PV_{T\text{-}CAR}$ and physical match performance during 11v11 matches and 7v7 small-sided games format. Moreover, our results suggest that a better performance on the T-CAR is associated with a greater ability to perform HIA regardless of age, maturity and body size-associated variations. These findings are consistent with our initial hypothesis and promote the T-CAR as an appropriated field test to estimate the match-related physical performance capability in male youth soccer players.

While the Yo-Yo IR1 and the MSFT have been extensively documented in soccer players (Castagna et al., 2009, 2010; Rebelo et al., 2014; Williford et al., 1999), few studies have reported information on T-CAR performance in youth soccer players. The current study average for $PV_{T\text{-}CAR}$ (mean value 15.5 $km{\cdot}h^{-1}$) was similar to that of Teixeira et al. (Teixeira et al., 2014), who reported a $PV_{T\text{-}CAR}$ of 15.7 $km{\cdot}h^{-1}$ in 14-year-old soccer players competing at regional and national championships. Moreover, Salvador, Do, Cetolin, Teixeira and Guglielmo (2014) also showed similar performance levels on the T-CAR in 34 age-matched youth soccer players. These comparisons show the high level of intermittent endurance running capacity of the players in the current sample. In contrast, the $PV_{T\text{-}CAR}$ in our study was considerably lower than those reported for 16-year-old soccer players (16.5 ± 0.7 $km{\cdot}h^{-1}$) (Teixeira et al., 2015), junior soccer players (16.5 ± 1.0 $km{\cdot}h^{-1}$) (Da Silva et al., 2011) and elite-level futsal/soccer players (16.4 ± 0.9 $km{\cdot}h^{-1}$) (Dittrich, Da Silva, Castagna, De Lucas, & Guglielmo, 2011). This suggests that the age per se and perhaps the years of training in the sport may contribute to variations in the results (Roescher et al., 2010; Valente-Dos-Santos et al., 2012).

Supporting our hypothesis, the $PV_{T\text{-}CAR}$ showed significant moderate and very large correlations with the TD covered during 11v11 and 7v7 games, respectively. In addition, large to very large associations were observed between the $PV_{T\text{-}CAR}$ and the distance of HIR, sprinting and amount of HIA performed during 11v11 games. Similar results were also observed during the small-sided game format (7v7) used in the present investigation (Table 2). It has been proposed that these relationships reported here are probably due to 2 main reasons (Rampinini et al., 2007). First, a high aerobic fitness plays a key role in recovery during repeated bouts of high-intensity intermittent efforts (Tomlin & Wenger, 2001). Second, during repeated sprints, as compared with a single sprint, the contribution of the aerobic energy system tends to increase (Spencer, Bishop, Dawson, & Goodman, 2005).

These results are similar to those reported by studies demonstrating the validity of the Yo-Yo IR1 test in adult soccer players (Krustrup et al., 2003). Indeed, a very large correlation has been reported between the Yo-Yo IR1 (r = 0.73; P = 0.03; 95% CI = 0.68–0.83) and the MSFT (r = 0.75; P = 0.02; 95% CI = 0.58–0.73) tests with the amount of HIA in 14-year-old Italian soccer players (Castagna et al., 2009, 2010). These values are similar to the correlation values found in this study for $PV_{T\text{-}CAR}$ and HIA (r = 0.78; P < 0.001) (Table 2). Although the comparisons among these studies may be affected by differences in protocols or performance output, these findings suggest that the ability to cover a greater distance at high running speeds during a match is positively associated with intermittent endurance running capacity evaluated as $PV_{T\text{-}CAR}$. From a practical perspective, the activity profile of the players during varying small-sided game formats in soccer training has also been quantified as a measure of external training load (Hill-Haas et al., 2008). In this study, it was demonstrated that a higher $PV_{T\text{-}CAR}$ translated into a greater amount of HIA during a small-sided game format (7v7) (Table 2), suggesting that improvements in the intermittent endurance running capacity are required to enable players to cope with high external training loads during daily training routines.

In the present study, friendly matches were used in order to reduce match-to-match variability in running performance. The average absolute and relative TD covered by players in the 11v11 condition (7158.9 ± 653.4 m and 102.3 ± 9.33 $m{\cdot}min^{-1}$, respectively) are similar to those previously reported in studies with youth soccer players (Buchheit et al., 2010; Castagna et al., 2009, 2010). Furthermore, the results showed that players in the current sample were able to cover distances at HIA (1596.0 ± 366.0 m) in a manner similar to those reported in highly competitive matches (1632.0 ± 596.0 m) for age-matched elite youth soccer players (Buchheit, Horobeanu, Mendez-Villanueva, Simpson, & Bourdon, 2011). In addition, players presented mean values around 84.6% of HRmax during 11v11 games, which are similar to those previously described (Castagna et al., 2009, 2010). As a consequence of these similarities, in terms of physical performance, it seems unlikely that the players' activity profile has been underestimated by using friendly matches. Thus, these results provide further support for the validity of the experimental design used in this investigation.

The construct validity of a test may be assessed by comparing different groups of individuals with different abilities (Currell & Jeukendrup, 2008). During adolescence, it is possible that the construct validity of a test is affected by the maturity status of players (Carvalho et al., 2011). On the other hand, field tests that are not related to maturity status have been recommended to distinguish players by competitive level in team sports (Carvalho et al., 2011). Previous studies have reported that age and maturation in addition to body size variations have a substantial impact on the intermittent endurance running capacity and physical match performance during competitive matches in youth soccer players around adolescent growth spurt (Buchheit & Mendez-Villanueva, 2014; Buchheit et al., 2010). In a recent study, Teixeira et al. (2015) demonstrated that the T-CAR performance was not different among boys contrasting in skeletal maturity status during puberty in soccer players aged 10–15 years, but it was related to variation in body size and CA. Consequently, a better performance on the T-CAR, which implies a greater amount of HIA during matches (Figure 2), might be related to age- or body size-associated variations given that the sample of players of the current study had CAs ranging from 13.5 to 15.9 years and presented a wide range of variation in body size. Surprisingly, our results showed that significant differences (ES from moderate to very large) for the physical match performance variables still remained among players of contrasting performance on the T-CAR after controlling for CA, maturity and body size, supporting the discriminative ability of this novel field test to predict the ability to perform maximal intensity exercise during matches independent of the changes that occur with growth and biological maturation (Table 3). Perhaps, these findings could be explained, at least in part, by the variability in the years of practice in soccer-specific training of the players in our sample (1–4 years) and other factors not related to biological maturation such as differences in running pattern and motor coordination (Deprez et al., 2014; Roescher et al., 2010; Valente-Dos-Santos et al., 2012). Given the growing interest in the T-CAR, further studies are required to examine the relationship between the $PV_{T\text{-}CAR}$ and physical match performance from early adolescence to adulthood in female youth soccer players.

Conclusions

In summary, the present study gives empirical support for the validity of the T-CAR as an indicator of match-related physical performance in young male soccer players during adolescence. Moreover, players of contrasting T-CAR performance were successfully discriminated based on their ability to perform high-intensity intermittent efforts during matches, providing evidence for construct validity.

Practical applications

This study revealed that the T-CAR can be considered a potentially useful tool for coaches and fitness trainers to assess the intermittent endurance running capacity from $PV_{T\text{-}CAR}$ reached at the conclusion of this exhaustive intermittent test. In addition, the $PV_{T\text{-}CAR}$ can be used to prescribe individualised physical training in youth soccer players. Interestingly, youth players (under age 15) with a $PV_{T\text{-}CAR}$ equal to or higher than 15.6 $km{\cdot}h^{-1}$ achieve a greater amount of HIA during a soccer match and small-sided game training format. As a result, T-CAR may be used to evaluate the ability of young soccer players to perform intensively during training and competition independently from their developmental stage. The present findings are of practical relevance to assess youth soccer players' readiness to compete and to guide the attainment of the fitness requirements suggested for adult soccer.

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