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ABSTRACT

The purpose of this study was to examine the reliability and the association with relevant match activities (ecological validity) of an age-adapted field test for intermittent high-intensity endurance known as Yo-Yo intermittent recovery level 1 children test (YYIR1C) in young male soccer players. Twenty-eight young male outfield soccer players (age 11.1±0.9 years, height 142±4.4 cm, body mass 37.0±5.9 kg) with at least 2 years of experience in soccer competitions were tested twice using YYIR1C and an age-adapted competitive small-sided game (i.e., 9v9), 7 days apart in a random order. The YYIR1C performance showed an excellent relative (ICC=0.94) and a good absolute reliability (TEM as %CV=5.1%). Very large and significant associations were found between YYIR1C performance and match high-intensity activity (**r^2=0.53**). Large correlations were found between YYIR1C and match sprinting (**r^2=0.42**) and high-intensity metabolic power (**r^2=0.46**) distances. Match total distance was largely associated with YYIR1C (**r^2=0.30**). The results of this study showed that YYIR1C may be considered a valid and reliable field test for assessing intermittent high-intensity endurance in young male soccer players. Due to the relevance of aerobic fitness in youth soccer, future studies testing the sensitiveness of YYIR1C are necessary.

Key words: Yo-Yo test, intermittent endurance, small-sided games, match analysis, high-intensity

INTRODUCTION

Aerobic fitness is considered a relevant component of competitive soccer performance across genders and competitive levels (34). Descriptive studies reported that aerobic fitness was associated with match demands while longitudinal research designs showed the increasing relevance of aerobic fitness in male soccer players across the competitive levels (9, 10, 14, 35). Training studies provided evidence for a practically medium positive effect of aerobic fitness development on match performance, reported as total match distance, activities performed at high-intensity and technical-

tactical variables (18, 21). In this regard, aerobic fitness **has been shown** to foster passing ability after simulations of match high-intensity phases (22, 32). Additionally, aerobic fitness was reported to favour recovery from competitive matches (25, 27, 28).

Given the relevance of aerobic fitness in competitive soccer, a number of field tests were proposed with the aim of estimating its components with feasible procedures in soccer players (3). In soccer, the Yo-Yo intermittent recovery test in its level 1 version (YYIR1) has **been** shown to be particularly successful because of its validity and reliability (3). The YYIR1 has been shown to be a valid and reliable test for young (14–17 years) male soccer players and has been considered as a specific endurance test for youth soccer because of its association with match physical activities (9, 10, 14). Furthermore, longitudinal studies have shown YYIR1 to be useful in profiling specific endurance development in young male soccer players (14).

Despite the reported practical relevance of YYIR1 in youth soccer, recent studies proposed the development and use of age-adapted versions in order to account for differences in running economy when dealing with very young children (1, 6, 30, 31). This was the case of the YYIR1 children's test (YYIR1C), which was proved to be valid (i.e., construct validity) and reliable for 9–11-year-old male and female soccer players (6, 30, 31). However, these studies only addressed criterion and construct validity, leaving the issue of test specificity (i.e., ecological validity) speculative at best (14). Information about the ecological validity of YYIR1C would be of great interest for soccer scientists and coaches aiming to evaluate aerobic performance since the first stages of players' competitive careers (14).

The aim of this study was therefore to investigate the ecological validity and reliability of YYIR1C in 9–11-year-old male soccer players considered as the targeted age group for this selected field test (30, 31).

The working hypotheses assumed the likelihood of YYIR1C showing good reliability and a large association between the considered field test performance and match relevant activities (9, 10).

METHODS

Experimental Approach to the Problem

A descriptive correlative design was used in this study aiming at investigating the association between YYIR1C and match selected variables (i.e., ecological validity) (9, 10). Ecological validity was assessed plotting YYIR1C performance (i.e., distance covered at exhaustion) against players' match external-load assumed as distances covered in arbitrary chosen speed and metabolic power categories (9, 10). Absolute and relative reliability of the selected variables (YYIR1C variables and match activities) were assessed **7 days apart,** to evaluate this study design internal validity.

With the aim of accounting for differences in physical fitness, maturation and skill variations related to game understanding, competitive youth soccer is played as age-adapted small-sided games (19, 34). The Italian Football Federation (FIGC) considers the 9v9 paradigm suitable for the age group of the players considered in this study (11 years). In order to account for match-to-match variability, match analysis data were considered as the average of two friendly games performed 7 days apart on the same natural grass pitch and at the same time of day (15). Match analysis studies reported that part of match-to-match variability may be the result of the difference in opponents' fitness and skill level, making single match reports unreliable (17). In this study we aimed to reduce opponent variability, so players were randomly allocated to teams according to playing roles and analysis of players' match performance was only performed in between-teammates matches (15). In all 4 friendly 9v9 matches were played (i.e., a replication for each team for data reliability) resulting in 28 players data eligible for analyses out of the 32 observed in this study. The exclusion of the four players from data analysis was due to improper functioning of the heart rate (HR) monitors or

Global Position System units (GPS) caused by game between players collisions. The **match external** load variables considered in this study were tested for reliability, providing very large to nearly perfect intraclass correlation coefficients (ICC; 0.78 to 0.95) (15). In order to assess the players' match internal-load, HR and rating of perceived exertion (RPE, Börg CR10 scale) were assessed for each of the matches in question (15).

The YYIR1C and the 9v9 matches were performed 7 days apart with the field test completed by the **players** 72 hours before the matches.

Subjects

The participants were 28 young outfield male soccer players (age 11.1±0.9 years, height 142.0±4.4 cm, body mass 37.0±5.9 kg) with at least 2 years of experience in soccer competitions and training. The players were randomly selected from a semi-professional soccer academy after medical clearance. Team allocation was performed matching players for soccer skill and game understanding in order to promote homogeneous opposing teams. At the time of the study, the players trained three times a week with a competitive match at the weekend. All the procedures involved in this study were carried out during the competitive season of the players' regional federal championship (FIGC). Informed assent was obtained from each of the players and written informed consent from their parents or guardians after a detailed verbal and practical explanation had been given of the benefits and potential risks of the testing procedures considered in this study. The players were aware that they could withdraw from the study at any time without any penalty. All the procedures used in this study were approved by the Institutional Internal Research Board before the commencement of this study.

Procedures

The YYIR1C was developed with the aim of accounting for differences in running economy in children and has recently been reported to be a reliable and valid (construct validity) test for young soccer players of either gender (30, 31). This test uses the same acoustic progression but shorter distance compared to YYIR1 (6, 30, 31). Indeed, in the YYIR1C the children shuttle-run between two lines positioned 16 m apart, instead of 20 m, and walk over 4 m (instead of 5 m) in the 10 s active recovery period (1, 5). The test starts at 8.23 $km \cdot h^{-1}$ passing to 11.08 $km \cdot h^{-1}$ for the second stage and thereafter progress with speed increments of 0.121 $km \cdot h^{-1}$ until exhaustion (5). In this study, the players performed the YYIR1C on separate occasions (i.e., 7 days apart) in order to assess reliability according to the procedures suggested by Póvoas et al. (31).

According to FIGC rules, the 9v9 matches were played on a 45x65 m pitch in three playing periods of 20 minutes each, interspersed by 4 min intervals.

Match external load was assessed using GPS technology (K-GPS, Montelabbate, Pesaro, Italy) with units sampling at 20 Hz. The K-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 analysis in soccer (ICC=0.89–0.92, Typical Error of measurement=1.8–4.5% and r=0.78–0.89)(15). The K-GPS units (n=18) were fitted between the players' shoulders in purpose-built vests. Match analysis was performed according to the arbitrary speed zones suggested by Castagna et al. (9, 10) as follows:

- Total distance (m) covered during the match (TD)
- Standing (from 0 to 0.4 $km \cdot h^{-1}$)
- Walking (from 0.4 to 3.0 $km \cdot h^{-1}$)
- Jogging (from 3.0 to 8.0 $km \cdot h^{-1}$)
- Medium-intensity running (MIR, from 8.0 to 13.0 $km \cdot h^{-1}$)

- High-intensity running (HIR, from 13.0 to 18.0 $km \cdot h^{-1}$)
- Sprint running (SPR from >18.0 $km \cdot h^{-1}$)
- High-intensity activity (HIA=HIR+SPR).

The high-intensity distance covered with metabolic power equal to or above 20 $watt \cdot kg^{-1}$ (MPHI) was **used** in this study according to Osgnach et al. (29).

Thirty minutes after each of the matches, the players were asked to individually provide their RPE using Börg CR10 scale according to the procedures suggested by Foster et al. (16). Exercise HR (i.e., match and YYIRC) was monitored with long-range telemetry (Polar T2, Polar Electro Oy, Kempele, Finland). Peak YYIR1C HR (HR_{peak}) was used to normalise match HR (1, 5, 6, 30, 31).

All testing procedures were performed on separate days (7 days apart) at the same time of day, in order to account for circadian variation in human performance, and under similar weather conditions (18–22 C°, 70–75% humidity). Matches and YYIR1C were performed on the same natural grass soccer pitch. All players were familiarised with the procedures in question during dedicated training sessions in the month before the study. No substitutions were allowed in any of the match considered in this study to provide data consistency.

Statistical analyses

Results are expressed as means±standard deviation with 95% confidence intervals (95%CI) (20). Normality assumption was verified using the Shapiro-Wilk W-test. Associations between YYIR1C (i.e., distance covered at exhaustion and HR) and match activities considered as distance covered in selected arbitrary categories (see procedures) were assessed using Pearson's product-moment correlation coefficients **and reported as r and r^2**. The qualitative magnitude of associations was reported according to Hopkins (2002) as follows: trivial $r < 0.1$, small $0.1 \leq r < 0.3$, moderate $0.3 \leq$

144 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.
145 Differences between testing occasion (i.e., reliability assessment) of the match activities variables
146 and YYIR1C performance and HR were assessed with paired t-tests using a Bonferroni correction.
147 The Cohen's *d* was used to evaluate the effect size with values above 0.8, between 0.8 and 0.5,
148 between 0.5 and 0.2 and lower than 0.2 considered as large, moderate, small and trivial,
149 respectively (12). Variations in match activity values across playing periods (i.e., 3x20 min) were
150 tested with analysis of variance for repeated measures with the Bonferroni post-hoc test to account
151 for potential effect of fatigue. The intraclass correlation coefficient ($ICC_{3,1}$) with 95%CI was used
152 to calculate relative reliability of match and YYIR1C HR and of the values of match activities and
153 YYIR1C performance. The magnitude of the resulting $ICC_{3,1}$ were rated according to Coppieters et
154 al. (13). Additionally, absolute reliability was determined using the typical error of measurement as
155 a percentage of the coefficient of variation (TEM as %CV) with 95%CI (20) for the same variables.
156 Significance was set at 5% (p≤ 0.05).
157
158 **RESULTS**

159 The values of match activities are reported in table 1. Trivial non-significant differences were found
160 across the playing periods for each of the **variables**. Between-matches and between-YYIR1C
161 differences were trivial and not significant for any of the **variables** (*d*=0.1–0.2; P>0.10), supporting
162 the use of pooled data (i.e., case mean). Average YYIR1C (n=28) performance and HR_{peak} were
163 1013±452 m (488, 1538) and 201±7 bpm (191, 215), respectively. The YYIR1C performance and
164 HR_{peak} ICCs were 0.94 (0.90, 0.98) and 0.90 (0.78, 0.95), respectively. The TEM as %CV values
165 for YYIR1C performance and HR_{peak} were 5.1% (3.1, 7.7%) and 0.9% (0.8, 1.1%), respectively.

166 Mean match HR values were 149±8 (125, 164) beats·m^{-1}, corresponding to 74±14% (64, 87) of
167 HR_{max}. During the matches, 18±18% (9, 28) of the players' time was spent at intensity equal to or
168 above 90% HR_{max}. Mean post-match RPE was 3.6±0.4 AU.

The ICCs for mean match HR and HR>90% HR_{max} were 0.96 (0.94, 0.98) and 0.91 (0.89, 0.93), respectively. The corresponding values for TEM as %CV were 1.1% (0.8, 1.4) and 0.8% (0.6, 1.0), respectively.

A significant (P<0.01) very large association was found between average YYIR1C performance and mean HIA (r=0.73; 0.68, 0.76; **r^2=0.53**). The distances for SPR (r=0.65; 0.22, 0.87; **r^2=0.42**), TD (r=0.55; 0.20, 0.80; r^2=0.30) and MPHI (r=0.68; 0.23, 0.89; **r^2=0.46**) were largely (P<0.01) associated with YYIR1C. A nearly perfect correlation was found between MPHI and HIA during matches (r=0.96; 0.89 to 0.99; **r^2=0.92**; P=0.0001). Post-hoc power calculations showed a power higher than 80% for all the considered correlations at 5% significance.

------ Table 1 about here please ------

DISCUSSION

The YYIR1C was reported to have construct validity and excellent relative and good absolute reliability in youth soccer players of either gender (30, 31). **This is the first study to examine the ecological validity of the YYIR1C in young males playing competitive soccer**. The main outcome of this study was the large to very large associations found between match TD, HIA and MPHI and YYIR1C performance assumed as total distance covered in this test at exhaustion. This is in accordance with the original working hypothesis of this research.

The YYIR1C ecological validity was tested using the 9v9 paradigm according to the rules established by male youth soccer governing bodies (i.e., FIGC) (19). In order to reduce as much as possible the opponent bias usually encountered in championship matches, only between-teammates friendly matches were considered (15). During this form of competitive small-sided games, the players covered almost 3.5 km over a time frame of 60 min, comprising the sum of three playing periods of 20 min each. The resulting work rate of 58 $m \cdot min^{-1}$ was remarkably lower than that reported in adult (96–119 $m \cdot min^{-1}$) and in older youth soccer players (102 $m \cdot min^{-1}$) during

competitive 11v11 matches (9, 10, 15, 34). Recently, a relative work rate of 107 $m \cdot min^{-1}$ was found in 12-14-year-old players during 7v7 competitive matches (4). The lower work rate shown in this study may have been the result of differences in age and game understanding between the players in question, warranting future studies to provide evidence on the variables affecting match activities in this age group and also considering different playing paradigms. Trivial ($P>0.05$) differences in match activities between playing periods were detected, suggesting that the intermittent exposure in these 9v9 matches (3x20 min playing periods with 4 min intervals) enabled physical performance maintenance. Interestingly, 9v9 showed good match-to-match relative reliability for match high-intensity variables (i.e., HIA and MPHI), supporting the relevance of this small-sided game paradigm for male soccer players in this age group.

The players were able to maintain HIA across playing periods and matches (i.e., short-term relative reliability), achieving only 75% of HR_{max} during the friendly 9v9 under consideration. This was an average cardiovascular load considerably lower than that reported for youth soccer matches and the post-match RPE of the players (i.e., moderate-strong) may provide some indication of the competitive nature of the matches performed (4, 9, 10, 34). However, the players completed 18% of match playing time at HR equal to or above 90% of HR_{max}, a time frame that has been reported as effective for improving cardiac structure and function in soccer health interventions with children of the same age as those in this study (24). It might be speculated that the players were able to maintain their HIA by pacing their effort across the match to avoid undue fatigue. The very large association between match activities and intermittent aerobic fitness performance may partly provide a possible cause of the resulting match intensity. Additionally, the poor reliability of TD (ICC 0.39) may suggest that the players maintained their match HIA by pacing their lower-intensity activities during the match, thus affecting their perception of the average match intensity. The reported good reliability (ICC 0.68–0.81) of the high-intensity match variables (i.e., HIA, SPR and MPHI) considered in this study support the competitive nature of the 9v9 and suggests the

likelihood of an objective match-to-match consistency in game intensity. Given the nature of this study it is difficult to explain the reason for this occurrence as no technical-tactical analysis was carried out. These results confirm the internal validity of this research design in using 9v9 friendly games with peer teammates as a match paradigm to assess YYIR1C ecological validity. Indeed, this match paradigm was successful in providing practically stable HIA values considered as a relevant variable for evaluating players' functional physical performance (11, 15). Given the interest in age-adapted small-sided games in youth soccer for promoting individual and team skills development, further studies examining different game paradigms are warranted (19).

In this study, the players (n=28) covered a distance in the YYIR1C that was very similar (*d*=0.15, trivial) to that reported by Póvoas et al. (31) in male age-matched soccer players. The present investigation confirmed the satisfactory relative reliability of YYIR1C, reporting values that were very close to those previously reported in male soccer players of similar age and training background for distance covered (ICC 0.98 vs. 0.94) and HR_{peak} (0.90 vs. 0.90), respectively (31).

The result for absolute reliability of HR_{peak} assessed as %CV was satisfactory and similar to that reported for male and female soccer players of this study's age range (0.5 vs. 0.9%) (30, 31). However, this study's players showed less test-to-test absolute variation in YYIR1C performance (%CV 11.1 vs 5.1%) than previously found in a similar age group male soccer players (31). The reported age group variation in absolute reliability may be due to differences in the research design used and the selection of the players. The reported findings support the internal validity of this study design and the relevance of YYIR1C as a solid testing paradigm in male soccer players.

In this validation study, the results showed that YYIR1C was very largely correlated with match activities performed at high-intensity during age-adapted small-sided games such as the 9v9 match in question. Indeed, the activity performed at speeds equal to or above 13 $km \cdot h^{-1}$ showed a very large association with YYIR1C **(r^2=0.53),** a finding that was in line with other studies addressing ecological validity in youth soccer with other test paradigms (9, 10, 15).

The debated metabolic power approach was used to depict match high-intensity considering MPHI also (29). This metric was originally considered of interest for the integrated use of acceleration and speed in a same variable and was thus supposed to provide more insight into the player's external load (29). The metabolic approach was recently criticised with regard to its criterion validity and reported to be nearly perfectly associated with classic notations of match external load usually considered as representative of match high-intensity **(7, 11, 33). Using the same methods as the current study, Manzi et al. (26) reported that MPHI was ecologically valid in professional soccer players. That is,** distance covered at intensities equal to or above 20 watt·kg^{-1}, with variables describing players' aerobic fitness.

In this study, MPHI showed a large association **(r^2=0.46)** with YYIR1C, with a magnitude slightly lower than that reported for HIA. Interestingly, the results for the two considered metrics (i.e., HIA and MPHI) used to describe match external load performed at high-intensity were nearly perfectly correlated **(r^2=0.92).** This data further confirms what was reported recently by Castagna et al. (11) in professional players competing in European premier leagues tracked with multiple-camera systems (i.e., 25 Hz). Given this, the use of speed zones to identify intensity constructs should be preferred when dealing with GPS technology, as in this study, given the reported problems associated with the calculation of acceleration parameters when not using a proper accelerometer during physical match-performance tracking (2, 36).

Given the problems reported to be associated with GPS tracking (i.e., sampling at 10 Hz) in this study, the high-intensity construct was considered for activities performed at speeds equal to or higher than 13.0 km·h^{-1} according to Castagna et al. (8). The resulting good reliability of HIA found with this study design confirmed the internal validity of this study design and recommends the use of these procedures for detecting changes in match performance in youth soccer in future studies (15). **Future studies examining the responsiveness of YYIR1C in this population domain are warranted.**

PRACTICAL APPLICATIONS

The results of this study showed that intermittent high-intensity endurance as measured by YYIR1C may explain inter-subject variability in match physical performance in soccer, even at children's level (9, 10, 15). Specifically, individual YYIR1C performance was very largely associated with those match activities that were considered as representative of the external load at high-intensity (HIA, SPR and MPHI). Given that, aerobic fitness should be regarded as relevant in the development of physical fitness in children (i.e., 11 years) playing competitive soccer (14).

The 9v9 paradigm, with three 20 min playing periods, produced a reliable competitive paradigm useful for tracking players' high-intensity activities. Interestingly, the players spent 18% of playing time at HR equal to or above 90% of HR_{max}, which recommends the valence of this competitive small-sided game for the development of aerobic fitness in children (24).

In light of this study's results, YYIR1C may be considered as a valid and reliable test for evaluating intermittent high-intensity performance in children playing competitive soccer in the 9–11 years age span (30, 31).

The association of field test performance with match activities was considered as a viable approach for evaluating ecological validity (3, 9, 10, 15, 34). The existence of practically very large associations between test outcome (distance covered) and relevant metrics of match performance was assumed as evidence of field test specificity and of relevance for developing sport-specific test batteries in youth soccer (14). A large to very large association between match high-intensity variables (i.e., MPHI, SPR and HIA) and YYIR1C performance (i.e., distance covered) was shown, warranting this test ecological validity (23). Although ecological validity may justify preliminary interest in the relevance of YYIR1C for soccer performance, conclusive information about test specificity can only be achieved when test responsiveness (i.e., test capacity to track performance over the time) has been shown (23).

The YYIR1C performance showed a remarkable inter-subject variability with a group CV% of ~45%. This result may suggest the interest of using the YYIR1C speed at exhaustion as a normalizing variable for the considered match-activity categories. This may enable a more accurate evaluation of game demands **in young soccer.**

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Table 1. Match external-load variables considered in this study

Variable (units)	Mean±SD	95%CI	ICC (95%CI)	TEM% (95%CI)
TD (m)	3497±501	3277, 3718	0.39 (-0.03, 0.69)	12.1(1.4, 16.8)
HIA (m)	364±154	282, 446	0.81 (0.50,0.94),	1.2 (0.8, 2.0)
SPR (m)	7.5±4.8	6.5, 8.5	0.68 (0.40,0.84)	2.8 (2.2, 3.4)
MPHI (Watt·kg^{-1})	93±34	75, 111	0.71 (0.43,0.87)	5.1% (2.2, 8.0)

TD = total distance; HIA= High-intensity activity (High-intensity running + Sprint running); SPR= Sprint running; MPHI=high-intensity distance covered with metabolic power equal to or above 20 watt·kg^{-1}; ICC = intraclass correlation coefficient with 95% CI (confidence intervals); TEM% = typical error of measurement (TEM) expressed as a percentage of the coefficient of variation using 95% confidence limits (95% CL).