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ORIGINAL RESEARCH

Reliability and Construct Validity of Yo-Yo Tests in Untrained and Soccer-Trained Schoolgirls Aged 9–16

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Purpose: The reliability and construct validity of three age-adapted-intensity Yo-Yo tests were evaluated in untrained ($n = 67$) vs. soccer-trained ($n = 65$) 9- to 16-year-old schoolgirls. ***Methods***: Tests were performed 7 days apart for reliability (9- to 11-year-old: Yo-Yo intermittent recovery level 1 children's test; 12- to 13-year-old: Yo-Yo intermittent endurance level 1; and 14- to 16-year-old: Yo-Yo intermittent endurance level 2). ***Results***: Yo-Yo distance covered was 40% (776 ± 324 vs. 556 ± 156 m), 85% (1252 ± 484 vs. 675 ± 252 m) and 138% (674 ± 336 vs. 283 ± 66 m) greater ($p \leq .010$) for the soccer-trained than for the untrained girls aged 9–11, 12–13 and 14–16 years, respectively. Typical errors of measurement for Yo-Yo distance covered, expressed as a percentage of the coefficient of variation (confidence limits), were 10.1% (8.1–13.7%), 11.0% (8.6–15.4%) and 11.6% (9.2–16.1%) for soccer players, and 11.5% (9.1–15.8%), 14.1% (11.0–19.8%) and 10.6% (8.5–14.2%) for untrained girls, aged 9–11, 12–13 and 14–16, respectively. Intraclass correlation coefficient values for test-retest were excellent (0.795–0.973) in both groups. No significant differences were observed in relative exercise peak heart rate ($\%HR_{peak}$) between groups during test and retest. ***Conclusion***: The Yo-Yo tests are reliable for determining intermittent-exercise capacity and $\%HR_{peak}$ for soccer players and untrained 9- to 16-year-old girls. They also possess construct validity with better performances for soccer players compared with untrained age-matched girls, despite similar $\%HR_{peak}$.

Keywords: Intermittent exercise performance, YYIR1C, YYIE1, YYIE2, heart rate, girls

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It has been reported that total distance covered during elite female soccer matches is approximately 10 km, with 1.7 km completed at high-speed (18 km.h^{-1}) and average and peak heart rate values of 86% of maximum heart rate (HR_{max}) and 98%HR_{max}, respectively (19). Aerobic intermittent high-intensity performance is related to high-intensity soccer match activities and elite players perform more high-speed running and more sprinting than moderate-level players (5,17,19,20,37,42). This suggests the relevance of intermittent high-intensity testing to assess aerobic fitness capability in young soccer players across age and gender.

Despite the growing interest on female soccer, papers related to female training and performance are still limited and studies are lacking in youth female players (19). In U-18 female soccer players the total distance covered (9 km) and the distance covered at high-intensity (1 km) are similar to adult elite female players (2). Similarities between male and female internal match demands have suggested the use of male soccer paradigms to train and test female players (19). However, in female soccer players, the association between laboratory and field-tests to match external-load such as match high-intensity activity, was reported to be higher than that observed in male soccer players of similar competitive level (34). In light of these findings, female soccer match-performance seems to relay more on individual aerobic-fitness compared with the age and competitive level-matched male counterparts (12,34). Therefore, the interest on aerobic fitness for female soccer testing and training is warranted.

In childhood and adolescence, intermittent exercise seems to prevail in unstructured (i.e., recreational exercise) and structured (e.g., team sports) daily activities. Furthermore, children seem to tolerate and enjoy more intermittent than continuous exercise (44). In addition, it has been shown that aerobic performance can be successfully improved through intermittent high-intensity exercise in youngsters (6).

Since intermittent exercise performance is of relevance for health and performance in childhood and adolescence, fitness intermittent field-tests (i.e., logical validity) were recommended for testing aerobic fitness (5,7,9,15,21,33,35). Nevertheless, chronological age differences in aerobic performance (39) suggest the use of gender and age-adapted intermittent field tests to account for variations in performance capabilities.

The Yo-Yo intermittent tests are proposed as a viable field procedure for assessing intermittent high-intensity performance in team-sport players of different age groups as performance in these tests is closely correlated with the amount of high-intensity running during the matches (5,15,16,21,33,35,43). The Yo-Yo intermittent tests versions consist of 2 × 20-m shuttle-runs interspersed by active recovery periods and differ in initial running speed and recovery time (5–10 s) and distance covered (2 × 2.5-m and 2 × 5-m) to mimic the intermittency of team-sports activity and to elicit the recovery capabilities of performers (4). Recently, a modified Yo-Yo test protocol, the Yo-Yo intermittent recovery Level 1 children's test (YYIR1C), was proposed with the aim of enabling feasibility in children (9). Compared with the most popular versions (Yo-Yo intermittent recovery and Yo-Yo intermittent endurance level 1—YYIE1 and level 2—YYIE2), this modified version of the Yo-Yo tests, features shorter distances using the same acoustic protocol as the classic versions.

These tests are considered simple and inexpensive, and allow testing many participants at the same time, in field settings. Nevertheless, despite the Yo-Yo intermittent tests being extensively used in female soccer, the reliability and validity of these tests across the competitive ages are scarce (5) and have not yet been examined in female soccer players of 9–16-years, a life span considered as fundamental for female soccer performance development (19). Given the popularity of Yo-Yo tests in female soccer, information as per the reliability, validity and feasibility are of great practical interest. Therefore, the aims of this study were to examine the reliability of the Yo-Yo intermittent age-adapted tests (distance and HR_{peak}) in soccer-trained and untrained girls aged 9–16 years and the ability of these tests to discriminate between soccer-trained and untrained girls in different age groups (construct validity).

Methods

Study Design

The reliability of three Yo-Yo intermittent tests (YYIR1C, YYIE1 and YYIE2) was determined by a test-retest procedure performed within 7 days from the first test. Construct validity was determined by comparing the performance (distance covered in the tests) and the relative exercise peak heart rate (%HR_{peak}), i.e., HR expressed as a percentage of maximal individual HR, of the untrained and soccer-trained girls in the Yo-Yo intermittent tests, within each age group.

Participants

Participants were female students (n = 132, Porto District, Portugal) aged 9–16 years, divided into two levels of sport participation (67 untrained and 65 soccer-trained players). Information about sport participation level was obtained from the Physical Education (PE) teachers and coaches. Each level of sport participation group was divided into three age groups (ages 9–11, 12–13 and 14–16 years) according to the competitive age groups used by the Portuguese Football Federation. Chronological age and general anthropometric characteristics of the participants according to level of sport participation are presented in Table 1. The untrained group comprised students not involved at the time, or had not previously been involved, in any formal or informal sports practice. Female soccer players were training and competing in soccer for an average of 1, 2 and 4 years (9–11, 12–13

Table 1 Chronologic Age and Anthropometric Characteristics of the Untrained and Soccer-Trained Participants Per Age Group

	Untrained (n = 67)			Trained (n = 65)		
Variables	9–11 years (n = 22)	12–13 years (n = 20)	14–16 years (n = 25)	9–11 years (n = 24)	12–13 years (n = 20)	14–16 years (n = 21)
Chronological age	9.7 ± 0.5	12.4 ± 0.5	14.5 ± 0.7	9.7 ± 0.7	12.5 ± 0.9	14.8 ± 0.8
Body mass (kg)	38.7 ± 8.8 (26.0–62.9)	50.3 ± 8.6 (33.9–63.9)	54.3 ± 11.2 (41.1–98.2)	36.1 ± 6.8 (24.9–42.4)	55.2 ± 14.0 (39.2–95.0)	57.5 ± 8.5 (46.0–78.5)
Stature (cm)	143.4 ± 6.8 (126.0–158.0)	154.3 ± 6.0 (143.0–171.0)	157.7 ± 6.1 (146.0–169.0)	141.0 ± 5.3 (135.0–147.0)	157.7 ± 6.4 (146.0–171.0)	164.6 ± 7.6* (154.0–175.0)
Body mass index ($kg.m^{-2}$)	18.72 ± 3.95 (14.55–32.87)	21.06 ± 3.10 (15.10–26.55)	21.81 ± 3.79 (16.10–34.79)	17.30 ± 2.48 (13.66–19.62)	22.02 ± 4.50 (16.23–36.20)	21.60 ± 3.15 (17.57–25.63)
Fat mass (%)	22.3 ± 6.8 (8.3–37.4)	21.8 ± 7.1 (10.4–36.1)	25.8 ± 5.6 (16.5–39.9)	26.7 ± 0.5 (25.7–27.3)	28.0 ± 6.0 (21.8–47.9)	22.8 ± 5.3 (14.7–32.6)

Note. Values are means ± *SD* and range.

*Significantly different (p = .033) from untrained participants.

and 14- to 16-year-old groups, respectively) and affiliated to soccer clubs and competing at regional level at the time of the investigation. The training volumes of the female soccer players consisted of 2 × 60-min sessions per week for the 9–11 age group and 3 × 90-min sessions per week for the 12–13 and 14–16 age groups. No maturation status assessment was performed. Weight and body fat percentage were measured using a Tanita BC532 InnerScan body composition monitor (Tanita, Amsterdam, The Netherlands). Body mass index (BMI) was calculated as the ratio of body weight (kg) to body height (m^2). The pupils gave their verbal assent and their parents gave their written consent for participation in the study. The study was conducted in accordance with the Declaration of Helsinki and ethical approval was provided by the local Institutional Review Board.

Testing Procedures

Untrained girls were tested during the first day of their weekly PE classes and no vigorous physical activity was performed on the day before testing in the second school trimester. Students were advised to eat a normal diet, including carbohydrates, the day before testing and to eat lunch at least 2 hr before testing. The soccer players were tested in middle of the competitive season during their first weekly training session to avoid a cumulative effect of fatigue on test performance and at the end of the afternoon during their normal training schedule. The players were instructed to maintain their normal nutritional habits and their coaches were asked to continue with the usual training schedule during the testing period. Aiming at attaining maximal performance, all tests were performed in the participants' usual exercise settings (i.e., indoor futsal court for the untrained and on artificial turf soccer pitch for the soccer-trained girls). All tests were performed after a standardized warm-up, wearing the same footwear, on the same day of the week, at the same venue and time of day and under neutral environmental conditions.

A 10 min warm-up consisting of running at different intensities and changes of direction was performed before the tests. Different Yo-Yo intermittent tests were used for each age group according to their level of physical performance, ensuring that the test would last a minimum of 3 min to elicit a high aerobic loading and, preferably, maximal or near-maximal HRs (1,5). YYIR1C, YYIE1 and YYIE2 were considered for the 9- to 11-, 12- to 13- and 14- to 16-year-old girls, respectively (1,4). The selected Yo-Yo intermittent tests differ in initial running speed, increments in running speed throughout the test, distance covered, and recovery time and distance between each back and forth run. The interest of age-adapted tests to assess intermittent high-intensity endurance was provided by the documented chronological age-related decrease in cardiorespiratory fitness in girls and in boys (39). Consequently, different Yo-Yo intermittent tests, or levels within each test, are required for different age groups. In adolescent soccer players, reliability of the Yo-Yo intermittent tests (YYIR1 and YYIE1) has been shown to increase with age and to be higher in boys than in girls (5,21).

HR was recorded at 1-s intervals using Polar Team System 2 (Polar Electro Oy, Kempele, Finland) during the tests to determine HR_{peak}, i.e., the highest value registered during each test. The participants were acquainted with the tests and the use of HR monitors on a previous visit to the testing days. The best performance in the given Yo-Yo intermittent tests for each group was taken as a measure of the participants' intermittent endurance capacity and used for construct validity analyses.

Despite the fact that maturation has been reported as affecting physical performance in the age span considered (14,40,45), no maturation evaluation was performed in this study. Nevertheless, in male pubertal soccer players, the estimated maturity offset (36) did not confound YYIR1 performance (21,22).

Statistical Analyses

Reliability. Absolute reliability for distance and HR_{peak} in each of the three Yo-Yo intermittent tests was determined taking into consideration the coefficient of variation (CV), the typical error of measurement (TEM), absolute and expressed as a percentage of the CV (%CV), using 95% confidence limits (95% CL). The intraclass correlation coefficient ($ICC_{3,1}$) with 95% CI (confidence intervals) was used to calculate relative reliability (26,46). The ICC values were interpreted as follows (24): excellent (0.75–1.00), good (0.41–0.74), and poor (0.00–0.40). The individual distribution of differences was examined using Bland-Altman plots and related limits of agreements (LOA) (11,38). Measurement bias was tested for significance against the null hypothesis (paired *t* test against difference = 0).

Practical significance was provided using the Cohen's d effect size (ES, 0.1 = trivial, 0.2 = small, 0.5 = medium, 0.8 = large) (18) and the smallest worthwhile difference (SWD) assumed as 0.2xSD (27). The SWD values were also presented as a percentage of mean values in the test-retest.

The Student's paired *t* test was used to access differences between the test-retest in distance and HR_{peak}.

Validity. The Student's unpaired *t* test was used to assess chronological age and anthropometric measures baseline differences between the two levels of sport participation and to test construct validity. The data were tested for normality using the Shapiro-Wilk test.

The significance level was set at 0.05. The Statistical Package for the Social Sciences (SPSS Inc, version 20.0, IBM, Armonk, New York, USA) was used for all analyses. The results were presented as mean± *SD* (*SD*) and range.

Results

No significant differences were detected between the untrained and trained participants in relation to chronological age and anthropometric characteristics, except for stature in the 14- to 16-year-old group (Table 1).

Reliability

Reliability of distance and HR_{peak} in the Yo-Yo tests, for the untrained and soccer-trained participants per age group is presented in Table 2.

The ICC values for distance covered for both groups (trained and untrained) were considered as excellent ($p <$ .001). Bland-Altman plots are presented in Figures 1a-1c. Significant bias (*P*£0.014) was detected in the 14–16 (untrained) and 9–11 (trained) age groups.

The TEM as %CV values for distance covered during the tests were within 11–14% for the untrained group, and within 10–12% for the soccer-trained players (Table 2).

SWD for performance in the tests expressed as a percentage of mean values in the test-retest ranged from 4.3 to 7.3% for the untrained girls, and from 7.7 to 10.2% for the soccer-trained female players (Table 2).

The 95% ratio LOAs were -229.57 ÷ 93.57, -250.258 ÷ 240.26 and -97.99 ÷ 59.59 m for the untrained group and -229.57 ÷ 93.57, -375.14 ÷ 255.14 and -169.59 ÷ 186.74 for the soccer-trained group (YYIR1C, YYIE1 and YYIE2, respectively).

Cohen's d effect size values for the untrained group were rated as trivial for the untrained group, and from trivial to large for the soccer-trained group (Table 2).

There were significant differences between the distances covered in the test and retest in the 14- to 16-year-old untrained group and in the 9- to 11-year-old trained group ($p \leq .025$).

The HR_{peak} ICC for both the untrained and trained girls were considered as excellent ($p < .001$) (Table 2). The HR_{peak} TEM as %CV values were within 0.4–0.6% for the untrained group, and within 0.4–0.5% for the soccer-trained group. The difference bias for HR_{peak} was significant ($p \leq .027$) in the 9–11 age group (untrained and trained), and in the 14–16 age group (trained).

The SWDs ranged from 1 to 2 (0.7–1.0%) $b \cdot min^{-1}$ for the untrained girls, and from 1 to 2 (0.7–0.8%) $b \cdot min^{-1}$ for the soccer-trained girls (Table 2).

The 95% ratio LOAs were -6.71 ÷ 15.16, -10.45 ÷ 11.45 and -7.37 ÷ 12.09 m for the untrained group and -7.36 ÷ 14.70, -7.45 ÷ 8.52 and -9.48 ÷ 9.72 for the soccer-trained group (YYIR1C, YYIE1 and YYIE2, respectively).

Cohen's d effect size values for the untrained group were rated from small to medium for the untrained group, and from trivial to medium in the soccer-trained group (Table 2).

There were significant differences between the test and retest HR_{peak} values in the 9- to 11- and 14- to 16-year-old untrained groups and in the 9- to 11-year-old trained group ($p \leq .026$).

Validity

The soccer players' best performances in the Yo-Yo intermittent tests were significantly ($p \leq .010$) better than those of the untrained girls across all age groups (9–11, 12–13 and 14–16: 776 ± 324 vs. 556 ± 156 m, 1252 ± 484 vs. 675 ± 252 m and 674 ± 336 vs. 283 ± 66 m, respectively, (Figure 2). For the best performance in the YYIR1C, YYIE1 and YYIE2, Cohen's d effect size values were rated as moderate, small and large, respectively. No significant differences were detected in $\%HR_{peak}$ between the two levels of sport participation in both testing moments (Figure 3).

Discussion

The aims of this study were to examine the reliability of the Yo-Yo intermittent age-adapted tests (distance and HR_{peak}) in soccer-trained and untrained girls aged 9–16 years and the ability of these tests to discriminate between soccer-trained and untrained girls in different age groups (construct validity).

Table 2 Reliability of Distance and HR_{peak} in the Yo-Yo Tests for the Untrained and Soccer-Trained Participants Per Age Group

	Untrained (*N* = 67)			Trained (*N* = 65)		
Variables	9–11 years (*n* = 22)	12–13 years (*n* = 20)	14–16 years (*n* = 25)	9–11 years (*n* = 24)	12–13 years (*n* = 20)	14–16 years (*n* = 20)
Distance						
T1 (m)	521 ± 153	622 ± 232	256 ± 54	705 ± 316	1154 ± 442	644 ± 340
T2 (m)	528 ± 162	627 ± 212	275 ± 67	768 ± 331	1214 ± 487	635 ± 318
P value (T1 vs. T2)	0.663	0.860	0.025	0.001	0.112	0.670
CV (%)	9 ± 6	11 ± 7	9 ± 6	10 ± 8	9 ± 6	8 ± 7
ICC (95% CI)	0.89 (0.79–0.95)	0.87 (0.75–0.94)	0.80 (0.63–0.89)	0.97 (0.95–0.99)	0.95 (0.89–0.98)	0.97 (0.93–0.98)
TEM (CL)	1.12 (1.09–1.16)	1.14 (1.11–1.20)	1.11 (1.09–1.14)	1.10 (1.08–1.14)	1.11 (1.09–1.15)	1.12 (1.09–1.16)
TEM (%CV) (CL)	11.5 (9.1–15.8)	14.1 (11.0–19.8)	10.6 (8.5–14.2)	10.1 (8.1–13.7)	11.0 (8.6–15.4)	11.6 (9.2–16.1)
Cohen's effect size	-0.091	-0.040	-0.494	0.781	-0.389	0.083
SWD (absolute and relative)	30.5 (5.8%)	45.7 (7.3%)	11.5 (4.3%)	64.2 (8.7%)	91.6 (7.7%)	65.2 (10.2%)
HR_{peak}						
T1 ($b \cdot min^{-1}$)	202 ± 10	202 ± 8	201 ± 9	207 ± 9	201 ± 7	199 ± 8
T2 ($b \cdot min^{-1}$)	198 ± 10	201 ± 7	199 ± 7	203 ± 9	200 ± 8	199 ± 9
P value (T1 vs. T2)	0.002	0.693	0.026	0.021	0.690	0.923
CV (%)	2.0 ± 1.4	1.5 ± 1.3	1.5 ± 1.1	2.0 ± 1.3	1.4 ± 0.8	1.5 ± 0.9
ICC (95% CI)	0.88 (0.53–0.96)	0.84 (0.59–0.94)	0.88 (0.70–0.95)	0.85 (0.48–0.95)	0.92 (0.74–0.93)	0.91 (0.76–0.97)
TEM (CL)	1.02 (1.02–1.03)	1.02 (1.02–1.03)	1.02 (1.01–1.02)	1.02 (1.02–1.03)	1.01 (1.01–1.02)	1.02 (1.01–1.03)
TEM (%CV) (CL)	0.4 (0.4–0.6)	0.6 (0.5–0.9)	0.5 (0.4–0.6)	0.5 (0.4–0.8)	0.4 (0.3–0.7)	0.5 (0.4–0.6)
Cohen's d effect size	0.482	0.181	0.414	0.692	0.245	0.000
SWD (absolute and %)	1.9 (1.0%)	1.4 (0.7%)	1.5 (0.8%)	**1.7 (0.8%)**	1.4 (0.7%)	1.6 (0.8%)

Note. T1 = test; T2 = retest; CV = coefficient of variation; ICC = intraclass correlation coefficient with 95% CI (confidence intervals); TEM = typical error of measurement (TEM), absolute and expressed as a percentage of the CV (%CV), using 95% confidence limits (95% CL); SWD = smallest worthwhile difference (absolute and expressed as a percentage of mean values in the test-retest).

The validity and reliability of Yo-Yo intermittent tests have been studied in several age groups, in both genders and for different levels of performance (1,2,5,7,9,12,15,17,21,23,33,35,41,42). However, the reliability and construct validity of these tests has still to be ascertained for several age groups and different levels of sport participation, namely soccer-trained and untrained girls.

This study is the first to provide data on the reliability and construct validity of Yo-Yo intermittent tests in untrained and soccer-trained girls aged 9–16. The main findings were that the three age-adjusted Yo-Yo intermittent tests, (i.e., YYIR1C, YYIE1 and YYIE2) are reliable and able to discriminate between untrained and soccer-trained schoolgirls across the considered age-span.

The Yo-Yo intermittent tests under consideration were shown to be reliable irrespective of age and level of sport participation. In fact, the relative reliability assumed as ICC ranged from 0.80 to 0.97 ($p < .001$), which is considered as excellent. In addition, TEM as %CV, representing absolute reliability, showed values close to 10%, a reference threshold suggested for the practical acceptance of clinical variation (3,26). However, variables difference bias showed significant ($p \leq .014$) differences in the 14–16 age group (untrained, ES = small) and in the 9–11 age group (trained, ES = medium), and there were also significant differences between the test and retest values for these groups ($p \leq .025$), suggesting the likelihood of within-subjects differences of practical importance (15). The differences in the oldest age group could be related to the test probably being too demanding from a physical and physiological point of view. YYIE2 probably had a predominant anaerobic component, making it too difficult for this age group, as the distances covered were quite low, particularly for the untrained group (283 ± 66 m)

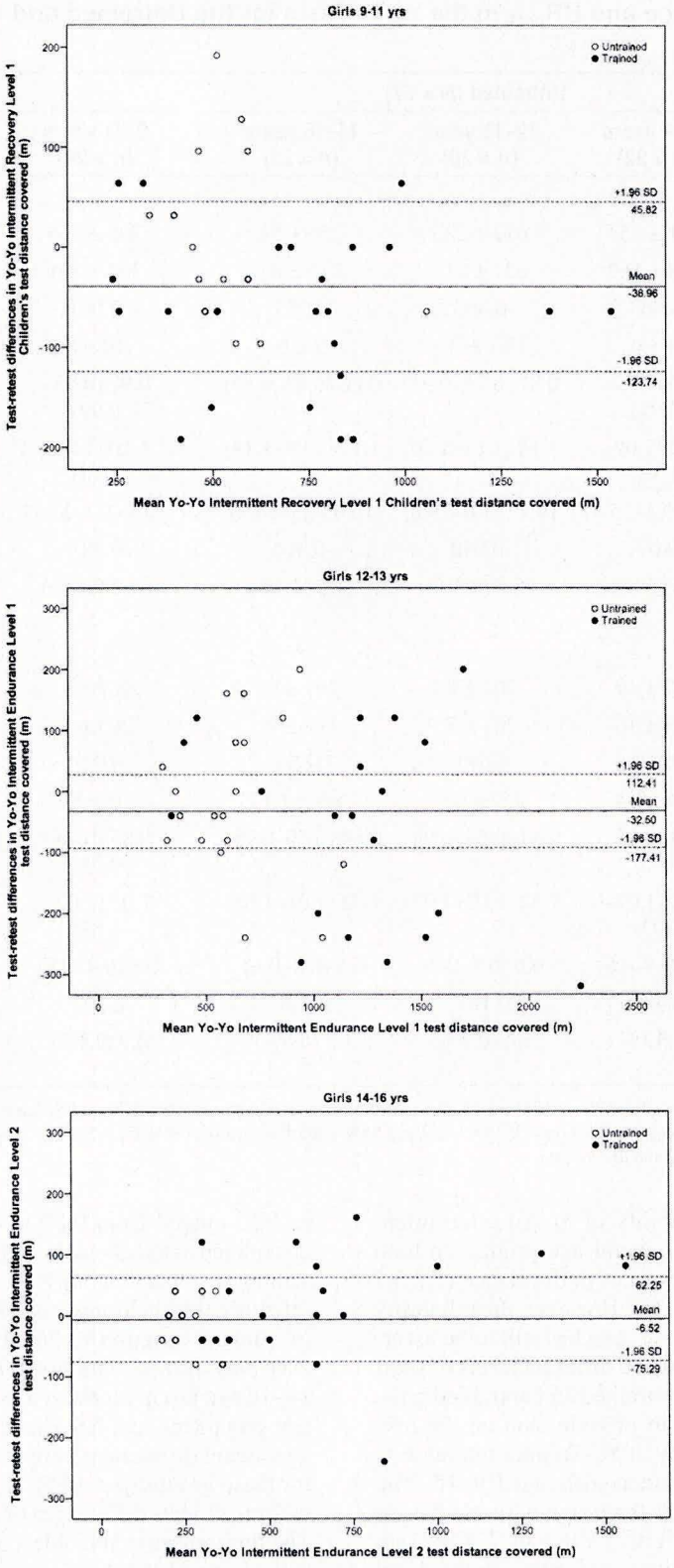

Figure 1 — Bland-Altman plots with 95% limits of agreement between the Yo-Yo intermittent test performances: (a) YYIR1C: n = 22 untrained (O) and n = 27 soccer trained (●) 9- to 11-year-old participants; (b) YYIE1: n = 25 untrained (O) and n = 23 soccer trained (●) 12- to 13-year-old participants; and (c) YYIE2: n = 25 untrained (O) and n = 20 soccer trained (●) 14- to 16-year-old participants.

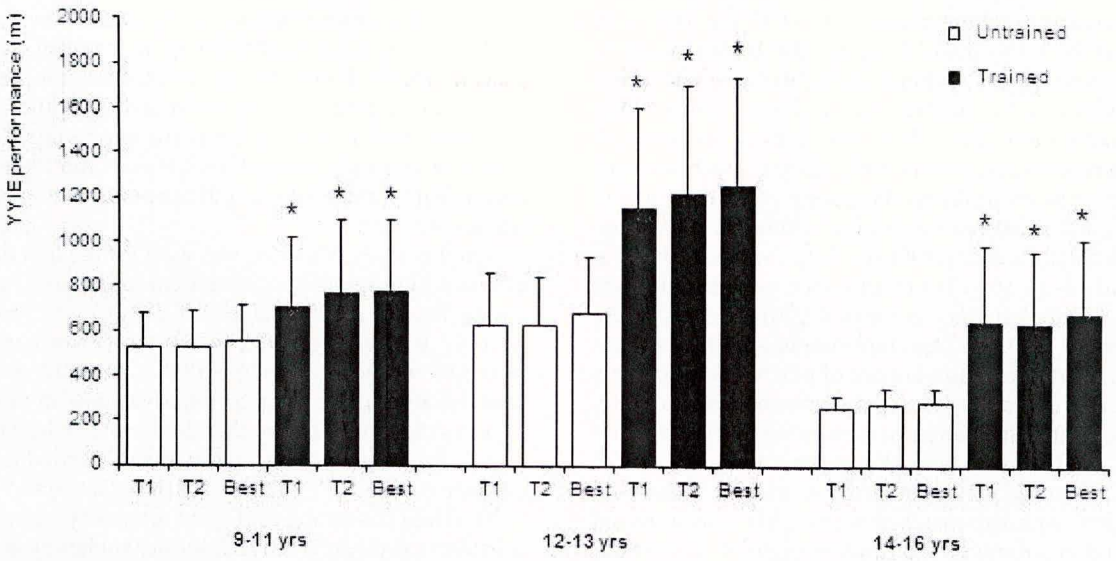

Figure 2 — Distance covered by the untrained and the soccer-trained participants in the test (T1), retest (T2) and best performance in the YYIR1C (9- to 11-year-old participants), the YYIE1 (12- to 13-year-old participants) and YYIE2 (14–16-year-old participants) (means ± *SD*). *: Significantly different ($p \leq .022$) from the untrained participants; years—yrs.

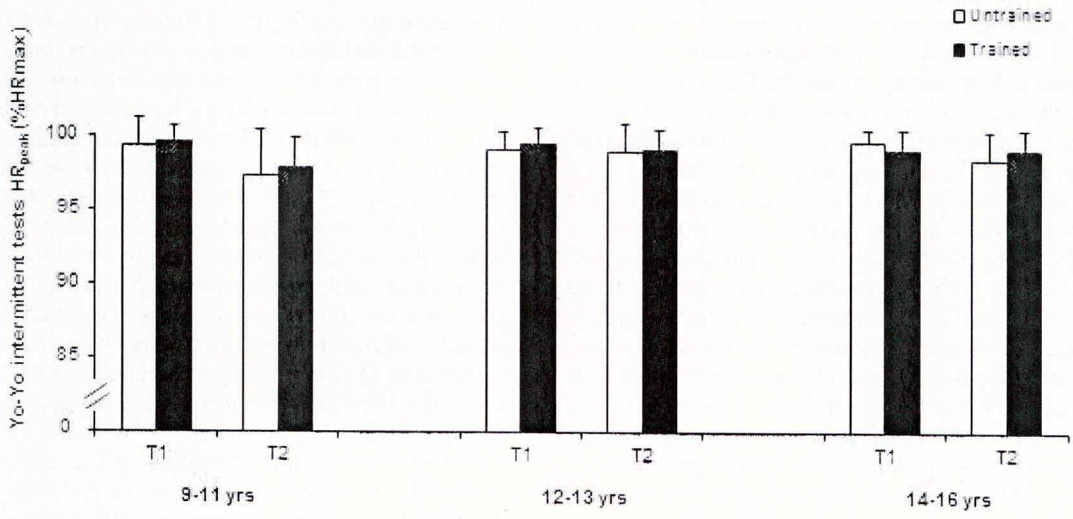

Figure 3 — Peak heart rate (HR_{peak}) expressed as a percentage of maximal heart rate ($\%HR_{max}$) for the untrained and trained participants in the test and retest in the YYIR1C (9–11-year-old participants), the YYIE1 (12- to 13-year-old participants) and YYIE2 (14- to 16-year-old participants). Data are presented as means± *SD* years—yrs.

(35). Despite the reported high reliability and construct validity of the YYIE2, it would be advisable to use, as an option, the YYIE1 for this age group (15).

The SWD was suggested as a measure of the practical minimum improvement of interest as a consequence of a training intervention (27). In this study, the SWDs for the soccer-trained girls were in the range 7–8%, a magnitude much lower than the improvements reported in the training studies with soccer players using Yo-Yo intermittent tests (20–50%) (5,33). The corresponding SWDs for the untrained group were in the range 4–6%.

Only one study has described the changes in Yo-Yo intermittent test performance (YYIR1C) in 8- to 9-year-old schoolchildren (9). The children showed a 25% increase in Yo-Yo performance after 6 weeks of high-intensity physical education classes. Nevertheless, as there are no studies involving training interventions in the age groups studied here, further studies are warranted.

In this research, internal load was assessed by monitoring exercise HR in all the participants under consideration. The results showed high $\%HR_{peak}$ reliability in all age categories and groups. Indeed, the ICC values

were rated as excellent (range: 0.84–0.92; $p < .001$) with TEM as %CV less than 1% (range: 0.4–0.6%) for all the calculations. These findings concur with the CV values of previous studies in male soccer players in the U13 to U17 age groups (21). These data provide evidence of the internal validity of this study design, which was able to elicit peak effort across the testing conditions in both groups and in all age categories. Although, there were significant differences in the test-retest values in the 9- to 11- and 14- to 16-year-old untrained groups and in the 9- to 11-year-old trained group ($p \leq .026$), the SWDs were very low (0.7–1.0%). Therefore, despite statistical significance, the differences were not of practical importance.

Construct validity assessed as known groups comparison is of interest when a test is examined for sport specificity (28). In this study, Yo-Yo intermittent performances of soccer-trained players of moderate training status were compared with age-matched active girls who were not involved in structured intermittent high-intensity training (i.e., soccer training and competitions). As expected, Yo-Yo intermittent test performances in the soccer-trained players group were significantly higher than those in the untrained group, with differences of 40%, 85% and 138% for the 9–11, 12–13 and 14–16 age groups, respectively. The Yo-Yo intermittent tests induced high HRs for all participants, with no significant differences in $\%HR_{peak}$ between the two levels of sport participation, in all age groups and in both testing moments. These results indicate that the tests elicited similar cardiovascular strain for both levels of performance. These findings are in line with Krustrup et al. (31), who reported an absolute but not a relative difference in physiological demands in YYIE2 between untrained subjects and male soccer players.

This is the first study to present distance and $\%HR_{peak}$ during Yo-Yo intermittent tests in untrained and soccer-trained girls aged 9–16 years. Distance covered in YYIR1C in 9–11-year-old untrained girls was lower than that reported for 6- to 9-year-old mixed untrained girls and boys (1), and for 6- to 7- and 8- to 9-year-old mixed untrained girls and boys (7). In the oldest-age soccer-trained group (14–16 years old), YYIE2 performance was lower than that reported for U17 elite and U19 elite and nonelite male soccer players (41,42), subelite U19 female soccer players, domestic level and elite youth and senior female soccer players (12).

In line with previous studies (29,30), the results of the current study indicate that soccer practice elicits a much higher cardiorespiratory fitness level in female children and adolescents. Recently, a study has shown that PE-based ball-game interventions consisting of high-aerobic-intensity indoor activities, including soccer, induce higher aerobic loading than circuit training, walking or Nintendo Wii boxing (9). Training interventions using soccer as an exercise mode showed a significant physical fitness improvement in respect of young schoolchildren's intermittent high-intensity performance (i.e., Yo-Yo intermittent tests) while traditional PE sessions showed no effects (7,9). Likewise, soccer training and competition impose a high aerobic and anaerobic training load, inducing positive changes in intermittent exercise capacity (5,32). It could be speculated that the association of soccer practice with sprint and strength training may constitute a viable strategy for improving specific fitness in female soccer players. Given the interest of concurrent training for strength and conditioning further studies are warranted.

In this study, YYIR1C was used for the first time to evaluate high-intensity intermittent endurance in very young female soccer players. YYIR1C was reported not only as detecting differences in test performance for mixed 6- to 9-year-old pupils (84%), but also as being sensitive to training-induced improvements in physical capacity (8). This test may therefore prove to be a useful tool for tracking cardiorespiratory fitness in childhood, as distance covered in YYIR1C is closely related to VO_{2max} (1,9). Given the established good reliability and proven construct validity of YYIR1C, further studies examining the ecological and criterion validity of this test in female youth soccer are necessary. YYIE2 seems mainly anaerobic for the 14- to 16-year-old untrained group. This is consistent with the decrease in cardiorespiratory fitness observed with age (39).

The detected differences in high-intensity intermittent endurance performance suggest that relative differences between untrained and soccer-trained female pupils in Yo-Yo intermittent performance increase with age in favor of soccer-trained players. It could be speculated that this was probably the effect of an age-dependent decrease in daily physical activity levels and physical fitness in untrained pupils (10,25). The cumulative effect of training and competition was considered as an independent variable of the age-related increase in physical fitness usually reported in young soccer players (5,42). In addition, the decline in cardiorespiratory fitness that occurs with age, usually attributed to increased adiposity associated with maturation (39), could in part be counteracted by exercise, thus increasing the differences between untrained and trained girls.

Nevertheless, one limitation of the current study is that the tests were carried out in different playing fields and with different footwear for the trained and the untrained group. No study has yet compared the physical and physiological demands of indoor and outdoor (artificial and natural turf) playing fields and footwear. Nevertheless, since locomotor activities, HR, blood lactate levels, and perceived exertion differ between sand, artificial turf, and asphalt (13), it could be expected that indoor and outdoor playing fields also differently impact on pupils' Yo-Yo performance.

Conclusion

In light of the results of this study, the Yo-Yo intermittent tests (YYIR1C, YYIE1 and YYIE2) are reliable tools for testing the intermittent exercise capacity and $\%HR_{peak}$ of girls in school and sports clubs, and for detecting differ-

ences in performance level between untrained and sports-trained girls across age groups from 9 to 16 years. As age increases, the relative differences in intermittent exercise capacity between untrained and the soccer-trained children and adolescent schoolgirls also increase, in favor of the soccer-trained girls, consequently suggesting the use of fitness-adapted field-tests to access fitness-related differences. Furthermore, since the Yo-Yo intermittent tests are well correlated with VO_{2max} in untrained subjects (1,31), these practical and low-cost field tests can be used to determine general aerobic fitness levels of 9- 16 years-old untrained and trained schoolgirls. The YYIE1 should be used for the 14- to 16-year-old untrained girls instead of the YYIE2.

References

1. Ahler T, Bendiksen M, Krustrup P, Wedderkopp N. Aerobic fitness testing in 6- to 9-year-old children: reliability and validity of a modified Yo-Yo IR1 test and the Andersen test. *Eur J Appl Physiol.* 2012; 112(3):871–876. PubMed doi:10.1007/s00421-011-2039-4
2. Andersen TB, Bendiksen M, Pedersen JM, et al. Kicking velocity and physical, technical, tactical match performance for U18 female football players–effect of a new ball. *Hum Mov Sci.* 2012; 31(6):1624–1638. PubMed doi:10.1016/j.humov.2012.07.003
3. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. *Sports Med.* 1998; 26(4):217–238. PubMed doi:10.2165/00007256-199826040-00002
4. Bangsbo J. Fitness Training in Football: A Scientific Approach. Bagsvaerd: HO & Storm; 1994.
5. Bangsbo J, Iaia FM, Krustrup P. The Yo-Yo intermittent recovery test: a useful tool for evaluation of physical performance in intermittent sports. *Sports Med.* 2008; 38(1):37–51. PubMed doi:10.2165/00007256-200838010-00004
6. Baquet G, Berthoin S, Gerbeaux M, Van Praagh E. High-intensity aerobic training during a 10 week one-hour physical education cycle: effects on physical fitness of adolescents aged 11 to 16. *Int J Sports Med.* 2001; 22(4):295–300. PubMed doi:10.1055/s-2001-14343
7. Bendiksen M, Ahler T, Clausen H, Wedderkopp N, Krustrup P. The use of Yo-Yo intermittent recovery level 1 and Andersen testing for fitness and maximal heart rate assessments of 6- to 10-year-old school children. *J Strength Cond Res.* 2013; 27(6):1583–1590. PubMed doi:10.1519/JSC.0b013e318270fd0b
8. Bendiksen M, Ahler T, Shumikhin D, Brito J, Wedderkopp N, Krustrup P, editors. Aerobic fitness and maximal heart rate testing in 6–9 yr old children: reliability, sensitivity and validity of the Yo–Yo IR1 test and the Andersen test. 7th World Congress on Science and Football; 2011; Nagoya, Japan.
9. Bendiksen M, Williams CA, Hornstrup T, et al. Heart rate response and fitness effects of various types of physical education for 8- to 9-year-old schoolchildren. *Eur J Sport Sci.* 2014; 14(8):861–869. PubMed doi:10.1080/17461391.2014.884168
10. Biddle SJ, Gorely T, Stensel DJ. Health-enhancing physical activity and sedentary behaviour in children and adolescents. *J Sports Sci.* 2004; 22(8):679–701. PubMed doi:10.1080/02640410410001712412
11. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet.* 1986; 1(8476):307–310. PubMed doi:10.1016/S0140-6736(86)90837-8
12. Bradley PS, Bendiksen M, Dellal A, et al. The application of the Yo-Yo intermittent endurance Level 2 test to elite female soccer populations. *Scand J Med Sci Sports.* 2014; 24(1):43–54. PubMed doi:10.1111/j.1600-0838.2012.01483.x
13. Brito J, Krustrup P, Rebelo A. The influence of the playing surface on the exercise intensity of small-sided recreational soccer games. *Hum Mov Sci.* 2012; 31(4):946–956. PubMed doi:10.1016/j.humov.2011.08.011
14. Buchheit M, Mendez-Villanueva A. Reliability and stability of anthropometric and performance measures in highly-trained young soccer players: effect of age and maturation. *J Sports Sci.* 2013; 31(12):1332–1343. PubMed doi:10.1080/02640414.2013.781662
15. Castagna C, Impellizzeri FM, Belardinelli R, et al. Cardiorespiratory responses to Yo-yo Intermittent Endurance Test in nonelite youth soccer players. *J Strength Cond Res.* 2006; 20(2):326–330. PubMed
16. Castagna C, Impellizzeri FM, Rampinini E, D'Ottavio S, Manzi V. The Yo-Yo intermittent recovery test in basketball players. *J Sci Med Sport.* 2008; 11(2):202–208. PubMed doi:10.1016/j.jsams.2007.02.013
17. Castagna C, Manzi V, Impellizzeri F, Weston M, Barbero Alvarez JC. Relationship between endurance field tests and match performance in young soccer players. *J Strength Cond Res.* 2010; 24(12):3227–3233. PubMed doi:10.1519/JSC.0b013e3181e72709
18. Cohen J. *Statistical power analysis for the behavioral sciences,* 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
19. Datson N, Hulton A, Andersson H, et al. Applied physiology of female soccer: an update. *Sports Med.* 2014; 44(9):1225–1240. PubMed doi:10.1007/s40279-014-0199-1
20. Davis JA, Brewer J. Applied physiology of female soccer players. *Sports Med.* 1993; 16(3):180–189. PubMed doi:10.2165/00007256-199316030-00003
21. Deprez D, Coutts AJ, Lenoir M, et al. Reliability and validity of the Yo-Yo intermittent recovery test level 1 in young soccer players. *J Sports Sci.* 2014; 32(10):903–910. PubMed doi:10.1080/02640414.2013.876088
22. Deprez D, Vaeyens R, Coutts AJ, Lenoir M, Philippaerts R. Relative age effect and Yo-Yo IR1 in youth soccer. *Int J Sports Med.* 2012; 33(12):987–993. PubMed doi:10.1055/s-0032-1311654
23. Fernandes L, Krustrup P, Silva G, Rebelo A, Oliveira J, Brito J. Yo-Yo Intermittent Endurance Test-Level 1 to monitor changes in aerobic fitness in pre-pubertal boys. *Eur J Sport Sci.* 2015; 16(2):159–164. PubMed
24. Fleiss JL. *Reliability of measurements: The design and analysis of clinical experiments.* New York, NY: Wiley; 1986.

25. Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet.* 2012; 380(9838):247–257. PubMed doi:10.1016/S0140-6736(12)60646-1
26. Hopkins W. Measures of reliability in sports medicine and science. *Sports Med.* 2000; 30(1):1–15. PubMed doi:10.2165/00007256-200030010-00001
27. Hopkins W, Marshall SC, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc.* 2009; 41(1):3–13. PubMed doi:10.1249/MSS.0b013e31818cb278
28. Impellizzeri FM, Marcora SM. Test validation in sport physiology: lessons learned from clinimetrics. *Int J Sports Physiol Perform.* 2009; 4(2):269–277. PubMed
29. Impellizzeri FM, Marcora SM, Castagna C, et al. Physiological and performance effects of generic versus specific aerobic training in soccer players. *Int J Sports Med.* 2006; 27(6):483–492. PubMed doi:10.1055/s-2005-865839
30. Krustrup P, Aagaard P, Nybo L, Petersen J, Mohr M, Bangsbo J. Recreational football as a health promoting activity: a topical review. *Scand J Med Sci Sports.* 2010; 20(Suppl. 1):1–13. PubMed doi:10.1111/j.1600-0838.2010.01108.x
31. Krustrup P, Bradley PS, Christensen JF, et al. The Yo-Yo IE2 Test: Physiological Response for Untrained Men vs Trained Soccer Players. *Med Sci Sports Exerc.* 2015; 47(1):100–108. PubMed doi:10.1249/MSS.0000000000000377
32. Krustrup P, Christensen JF, Randers MB, et al. Muscle adaptations and performance enhancements of soccer training for untrained men. *Eur J Appl Physiol.* 2010; 108(6):1247–1258. PubMed doi:10.1007/s00421-009-1319-8
33. Krustrup P, Mohr M, Amstrup T, et al. The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Med Sci Sports Exerc.* 2003; 35(4):697–705. PubMed doi:10.1249/01.MSS.0000058441.94520.32
34. Krustrup P, Mohr M, Ellingsgaard H, Bangsbo J. Physical demands during an elite female soccer game: importance of training status. *Med Sci Sports Exerc.* 2005; 37(7):1242–1248. PubMed doi:10.1249/01.mss.0000170062.73981.94
35. Krustrup P, Mohr M, Nybo L, Jensen JM, Nielsen JJ, Bangsbo J. The Yo-Yo IR2 test: physiological response, reliability, and application to elite soccer. *Med Sci Sports Exerc.* 2006; 38(9):1666–1673. PubMed doi:10.1249/01.mss.0000227538.20799.08
36. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc.* 2002; 34(4):689–694. PubMed doi:10.1097/00005768-200204000-00020
37. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci.* 2003; 21(7):519–528. PubMed doi:10.1080/0264041031000071182
38. Nevill AM, Atkinson G. Assessing agreement between measurements recorded on a ratio scale in sports medicine and sports science. *Br J Sports Med.* 1997; 31(4):314–318. PubMed doi:10.1136/bjsm.31.4.314
39. Ortega FB, Ruiz JR, Castillo MJ, et al. Health-related physical fitness according to chronological and biological age in adolescents. The AVENA study. *J Sports Med Phys Fitness.* 2008; 48(3):371–379. PubMed
40. Philippaerts RM, Vaeyens R, Janssens M, et al. The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci.* 2006; 24(3):221–230. PubMed doi:10.1080/02640410500189371
41. Rebelo A, Brito J, Maia J, et al. Anthropometric characteristics, physical fitness and technical performance of under-19 soccer players by competitive level and field position. *Int J Sports Med.* 2013; 34(4):312–317. PubMed
42. Rebelo A, Brito J, Seabra A, Oliveira J, Krustrup P. Physical match performance of youth football players in relation to physical capacity. *Eur J Sport Sci.* 2014; 14(Suppl. 1):S148–S156. PubMed doi:10.1080/17461391.2012.664171
43. Souhail H, Castagna C, Mohamed HY, Younes H, Chamari K. Direct validity of the yo-yo intermittent recovery test in young team handball players. *J Strength Cond Res.* 2010; 24(2):465–470. PubMed doi:10.1519/JSC.0b013e3181c06827
44. Timmons BW, Bar-Or O. RPE during prolonged cycling with and without carbohydrate ingestion in boys and men. *Med Sci Sports Exerc.* 2003; 35(11):1901–1907. PubMed doi:10.1249/01.MSS.0000093752.46408.AF
45. Vaeyens R, Malina RM, Janssens M, et al. A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *Br J Sports Med.* 2006; 40(11):928–934, discussion 934. PubMed doi:10.1136/bjsm.2006.029652
46. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res.* 2005; 19(1):231–240. PubMed