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ORIGINAL ARTICLE

Yo-Yo Intermittent Endurance Test-Level 1 to monitor changes in aerobic fitness in pre-pubertal boys

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Abstract
The present study aimed to examine the performance and heart rate responses during the Yo-Yo Intermittent Endurance Test-Level 1 (Yo-Yo IE1) in children under the age of 10. One hundred and seven male children (7–9 years) performed the Yo-Yo IE1 at the beginning (M_1), middle (M_2) and end (M_3) of the school year. Data from individual heart rate curves of the Yo-Yo IE1 were analysed in order to detect the inflection point between an initial phase of fast rise in heart rate values and a second phase in which the rise of the heart rate values is much smaller. The distance covered in the Yo-Yo IE1 improved from M_1 to M_3 (884 ± 496 vs. 1032 ± 596 m; $p < 0.05$; $d = 0.27$), with intermediate values for M_2 (962 ± 528 m). Peak heart rate (HR_{peak}) decreased from M_1 to M_2 and M_3 (204 ± 9, 202 ± 9 and 200 ± 9 bpm, respectively; $p < 0.05$; d = 0.25–0.42). The 7th shuttle of the test (280 m), corresponding to 2.5 min, was identified as the inflection point between the two phases. Also, absolute heart rate at the 7th shuttle decreased progressively throughout the year (185 ± 9, 183 ± 10, and 179 ± 10 bpm; $p < 0.05$; d = 0.31–0.61). The present study provides evidence of the usefulness of a maximal as well as a submaximal version of Yo-Yo IE1 as a tool to monitor changes in aerobic fitness in pre-pubertal children.

Keywords: *Youth, health, heart rate, cardiovascular, cardiorespiratory, YYIE1 testing*

Introduction

Physical education classes are the most privileged context for the promotion of public health through physical activity in children (Sallis & McKenzie, 1991). The explanation for this lies on that physical education is a compulsory school activity in most countries of the world, it has proper guidance/supervision by teachers that follow established government programmes and usually takes place more than once a week (Guerra, Nobre, da Silveira, & Taddei, 2013; Scheffler, Ketelhut, & Mohasseb, 2007). Likewise, regular testing of children's cardiorespiratory fitness in school contexts would provide precious information about the development of fitness levels during childhood. Also, it could provide relevant indications on the necessary stimuli for the prevention of long-term risk of developing obesity and cardiovascular disease in adult life (Bendiksen, Ahler, Clausen, Wedderkopp, & Krustrup, 2013).

The Yo-Yo tests have been described as reliable and valid to measure cardiovascular fitness in children younger than 10 years (Ahler, Bendiksen, Krustrup, & Wedderkopp, 2012). In fact, knowledge about the intermittent exercise capacity of children is of great interest since most of the physical activities that take place in the schoolyard and sports clubs are intermittent in nature (Bendiksen et al., 2013). The Yo-Yo tests (Bangsbo, 1996), especially the Intermittent Recovery level 1 and level 2 and the Intermittent Recovery level 1 children's test (YYIR1C), have been extensively used as a tool

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to assess cardiorespiratory fitness in different populations (Castagna, Impellizzeri, Chamari, Carlomagno, & Rampinini, 2006; Krustrup et al., 2003, 2006; Rebelo et al., 2012). The tests have the advantage of being inexpensive and simple to use; up to 15 individuals can be tested simultaneously (Bangsbo, 1996). The tests can also be used as a tool to measure maximal heart rate and are well correlated with aerobic fitness (Ahler et al., 2012; Bendiksen et al., 2013, 2014). The tests are sensitive to rapid changes in fitness level of adults, namely velocity and strength, and can discriminate between groups of distinct exercise capacity (Ahler et al., 2012; Bangsbo, Iaia, & Krustrup, 2008; Castagna et al., 2006; Seabra et al., 2012). However, information regarding young children is sparse.

Nonetheless, maximal testing presents several limitations, namely the need of completing the exercise until exhaustion (Krustrup et al., 2003). Thus, the use of submaximal versions could eliminate these constrains and allow the establishment of a more regular testing of cardiorespiratory fitness (Bendiksen et al., 2013; Bradley et al., 2011). For this purpose, in the present study, we utilised the Yo-Yo Intermittent Endurance Test-Level 1 (Yo-Yo IE1), which has proven to be affected by submaximal cardiorespiratory fitness-related variables (Castagna et al., 2006). Also, to our knowledge, no study so far has been conducted with the Yo-Yo IE1 in children under the age of 10. Therefore, the present study aimed to investigate the usefulness of a submaximal version of Yo-Yo IE1 as a tool to monitor changes in cardiorespiratory fitness in school children aged 7–9 years.

Methods

The sample consisted of 107 boys aged 8.5 ± 0.8 (range: 7.8–9.3) years. Height, weight and body mass index were: 131.5 ± 8.4 cm, 32.6 ± 8.3 kg and 18.6 ± 3.2 kg/m^2, respectively. The children were recruited in six elementary schools of the same community. The study design and the procedures used are in accordance with ethical standards and the Declaration of Helsinki. The local University Ethics Committee approved the study. All children were informed about the aims of the study; parents or legal guardians were fully informed about the risks associated with study participation and provided written informed consent.

The measurements took place at three distinct time points during the academic year: at the beginning (M_1), middle (M_2) and end (M_3) of the school season, corresponding to the months of October 2010 and February and May, 2011. During this period all participants were engaged with regular physical education classes. Generally, school-based physical education classes consisted of a general warm-up, technical exercises and small-sided games of team-sports such as football, handball and basketball, gymnastics and recreational activities lasting a total of 45 min. The emphasis of the physical education classes was made on several different sports, according to the timing of the year and the National programme for physical education. At each of the time points the data were collected in two sessions, two days apart. The first session was used for anthropometric measurements, 15-m sprint test and jumping height; the second session was used for evaluation of cardiorespiratory fitness.

Height was measured with a stadiometer (model 708, Seca, Hamburg, Germany); weight and percentage of body fat were assessed with a Tanita Inner Scan (BC-532, Tanita, Hoofddorp, the Netherlands). Duplicate measures were taken for each individual and the average was used for analysis. Children wore light clothing and shoes were removed.

With the exception of anthropometry and physical activity, all tests were administered indoors on a multi-sports ground. Prior to fitness testing, the children performed a 12-min warm-up consisting of light jogging and stretching exercises, as well as familiarisation trials of each test. Speed was evaluated with a 15-m sprint test. Elapsed times were measured using three pairs of photoelectric cells (Speed Trap II, Brower Timing Systems, Gresham, OR, USA), positioned at the starting line, and at 5 m (5-m sprint) and 15 m (15-m sprint). Children were instructed to run as fast as possible from a standing position 30 cm behind the starting line. The better (fastest) of 2 trials was retained for analysis. Speed evaluation on young children has proven to be reliable and valuable (Douma-van Riet et al., 2012; Rumpf, Cronin, Oliver, & Hughes, 2011). Jumping height was evaluated with a countermovement jump (CMJ) on a special mat (Digitime 1000, Digitest, Finland). For the CMJ, the child was standing erect; after flexing the knees to the squat position, he jumped vertically as high as possible maintaining hands on hips. Two trials were given for each jump and the better of the two trials was retained for analysis. CMJ evaluation has proven to be reliable on young children (Acero et al., 2011). The Yo-Yo IE1 was used to evaluate cardiovascular fitness (Bangsbo, 1996) and to obtain submaximal and maximal heart rate values. Research has proven that an adapted version of this test can be used as an indicator of cardiorespiratory fitness for children of this age (Ahler et al., 2012). The test required repeated 2 × 20 m shuttle runs between a start and finish line, at progressively increased speeds controlled by audio bleeps from a CD player; there was a 5-s period of recovery between runs. The aim of the test was to perform as many shuttles as possible. When the individual failed twice to reach the finish line in time, the distance covered was recorded and used as the test result. Only one trial was given. Heart rate was measured using Polar Team System™ (Polar Electro OY, Kempele, Finland) heart rate monitors set to record in 5-s intervals.

Descriptive statistics (mean ± standard deviation) were calculated. Data from the individual heart rate curves of the Yo-Yo IE1 tests were analysed in order to detect the inflection point between (1) an initial phase of fast rise in heart rate values, and (2) a second phase, in which the rise of the heart rate values is much smaller. The inflection point was detected through a visual analysis of dispersion plots containing information from the entire sample (Figure 1). The 7th shuttle was identified as the inflection point between the two phases of the test (before and after the 7th shuttle). Linear regression models were used to obtain the slope (β) values for the two phases. Significant differences were detected in β values between the two phases (13.37 ± 2.50 vs. 0.96 ± 0.74, $p < 0.001$, $d = 6.73$). Differences between the three evaluation time points were obtained using repeated measures ANOVA. Bonferroni post-hoc comparisons were used to discriminate those differences. Standardised differences in means (effect sizes, d) were computed for comparisons. Effect sizes were classified as trivial ($d < 0.2$), small ($0.2 < d < 0.6$) moderate ($0.6 < d < 1.2$), large ($1.2 < d < 2.0$), very large ($2.0 < d < 4.0$), nearly perfect ($d > 4.0$) and perfect (d = infinite) (Hopkins, 2010). Pearson correlations (r) were calculated and classified as trivial ($r < 0.1$), small ($0.1 < r < 0.3$) moderate ($0.3 < r < 0.5$), large ($0.5 < r < 0.7$), very large ($0.7 < r < 0.9$), nearly perfect ($0.9 < r < 1$) and perfect ($r = 1$) (Hopkins, 2010). Percentages of changes were calculated for the physical fitness parameters, in order to more easily express the differences between the three evaluation moments. The coefficient of variation between the three moments of testing was also calculated for all the tests. A stepwise linear regression analysis was employed to verify the impact of physical fitness variables on the performance of the Yo-Yo IE1 test. Significance was set to $p < 0.05$.

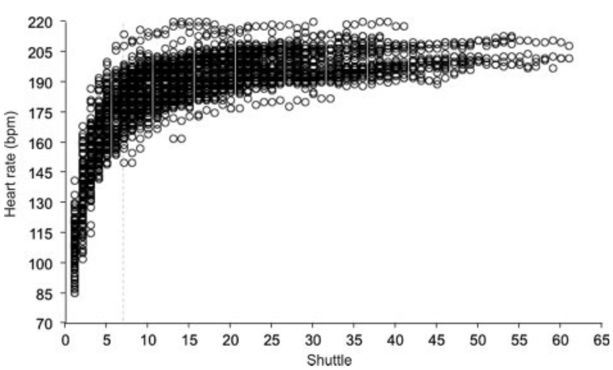

Figure 1. Heart rate (bpm) per shuttle of the Yo-Yo IE1 test for the entire sample. Vertical dotted line represents shuttle 7.

Results

Table I shows anthropometry and physical fitness values for the three evaluation time points. Weight was increased significantly during the year (32.4 ± 8.3, 34.0 ± 8.5, and 34.9 ± 8.5 kg, respectively; $p < 0.05$; $d_{m1-m2} = 0.19$, $d_{m2-m3} = 0.10$, $d_{m1-m3} = 0.30$). Sprint times both for 5 and 15 m were improved from M_1 and M_2 to M_3 (1.35 ± 0.10, 1.34 ± 0.10 vs. 1.29 ± 0.10 s; $p < 0.05$; $d_{m1-m3} = 0.60$, $d_{m2-m3} = 0.50$; 3.30 ± 0.23, 3.26 ± 0.24 vs. 3.18 ± 0.24 s; $p < 0.05$; $d_{m1-m3} = 0.55$, $d_{m2-m3} = 0.40$). No differences were found between the three time points for CMJ (21.0 ± 4.2, 21.4 ± 4.3, and 22.2 ± 5.4 cm, respectively; $p > 0.05$).

Figure 2 present, respectively, distance covered for Yo-Yo IE1 test, absolute HR at the 7th shuttle and HR_{peak} for Yo-Yo IE1 and $\%HR_{peak}$ at the 7th shuttle in M_1, M_2 and M_3. A significant improvement of 17% was detected between M_1 and M_3 for the distance covered (884 ± 496 vs 1032 ± 596 m; $p < 0.05$; $d = 0.27$), with intermediate values for M_2 (962 ± 528 m). HR_{peak} decreased from M_1 to M_2 and M_3 (204 ± 9, 202 ± 9 and 200 ± 9 bpm; $p < 0.05$; $d = 0.25$–0.42). Likewise, HR at the 7th shuttle

Table I. Comparisons between the three evaluation time points (M_1, M_2 and M_3) in age, anthropometry and physical fitness.

	M_1	M_2	M_3	p
Age (years)	8.5 ± 0.8	9.0 ± 0.8	9.5 ± 0.8	<0.005
Weight (kg)	32.4 ± 8.3[a]	34.0 ± 8.5[a]	34.9 ± 8.5[a]	<0.005
Height (cm)	131.3 ± 8.4	132.1 ± 8.2	135.0 ± 8.4[b]	<0.005
Physical fitness				
5-m sprint (s)	1.35 ± 0.10	1.34 ± 0.10	1.29 ± 0.10[b]	<0.005
15-m sprint (s)	3.30 ± 0.23	3.26 ± 0.24	3.18 ± 0.24[b]	<0.005
CMJ (cm)	21.0 ± 4.2	21.4 ± 4.3	22.2 ± 5.4	>0.005

CMJ, countermovement jump.
[a]Significant difference compared to all moments; [b]Significant differences compared to M_1 and M_2.

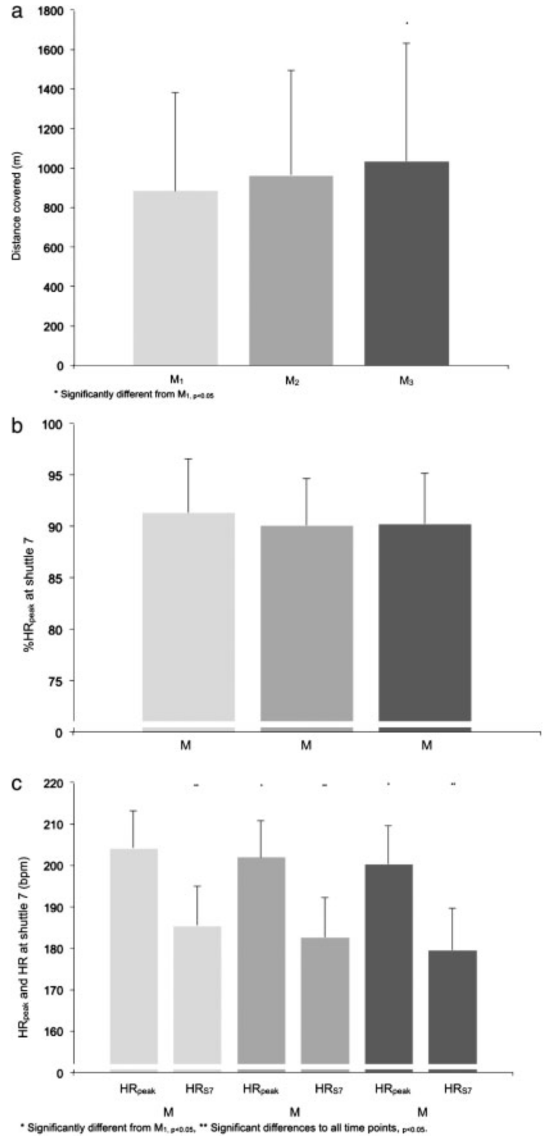

Figure 2. (a) Distance covered (m) in Yo-Yo IE1 test at beginning (M_1), middle (M_2) and end (M_3) of the school season; (b) percentage of HR_{peak} at Yo-Yo IE1 shuttle 7 test at beginning (M_1), middle (M_2) and end (M_3) of the school season; and (c) peak HR (HR_{peak}) and shuttle 7 HR (HR_{S7}) values (bpm) in Yo-Yo IE1 test (2c) at beginning (M_1), middle (M_2) and end (M_3) of the school season.

decreased progressively throughout the year (185 ± 9, 183 ± 10, and 179 ± 10 bpm, respectively; $p < 0.05$; d_{m1-m2} and d_{m2-m3} = 0.31, d_{m1-m3} = 0.61). No significant differences were found in % HR_{peak} at the 7th shuttle between the three evaluation moments (91.3 ± 5.2 vs. 90.1 ± 4.5 vs. 90.2 ± 4.9% HR_{peak}, respectively; $p > 0.05$). The coefficient of variation of the distance covered on the three Yo-Yo IE1 test was of 49.7%.

Large to very large inverse correlations were found between $\%HR_{peak}$ at the 7th shuttle and distance covered in the Yo-Yo IE1 test for M_1 ($r = -0.66$; $p < 0.01$), M_2 ($r = -0.70$; $p < 0.01$) and M_3

Table II. Multiple linear regression, adjusted coefficient estimates and 95% confidence intervals (CI) for distance covered in the Yo-Yo IE1 (dependent variable) for the three evaluation time points (M_1, M_2 and M_3).

	B (95% CI)	p
Countermovement jump[a]		
M_1	–	–
M_2	0.41 (0.22 to 0.61)	<0.001
M_3	0.27 (0.02 to 0.52)	0.037
15-m sprint		
M_1	–0.42 (–0.62 to 0.23)	<0.001
M_2	–0.23 (–0.42 to –0.03)	0.024
M_3	–0.35 (–0.60 to –0.09)	0.009

[a]Countermovement jump was excluded from the regression model on M_1.

($r = -0.73$; $p < 0.01$). Moderate inverse correlations were found between the absolute HR at the 7th shuttle and distance covered in the Yo-Yo IE1 test for M_1 ($r = -0.43$; $p < 0.01$), M_2 ($r = -0.34$; $p < 0.01$) and M_3 ($r = -0.36$; $p < 0.01$).

A stepwise regression model including both CMJ and 15-m sprint performance as independent variables presented a significant predictive value on the performance of the Yo-Yo IE1 test on M_1 ($r^2 = 0.18$, $p < 0.001$), M_2 ($r^2 = 0.33$, $p < 0.001$) and M_3 ($r^2 = 0.31$, $p < 0.001$).

Discussion

The results of the present study indicate that boys under the age of 10 improved performance in fitness tests throughout the academic year along with reductions in submaximal HR values. Performance in the Yo-Yo IE1 increased throughout the school year, with the distance covered in the test increasing by 17% from the initial to the final evaluation. Furthermore, we observed that a submaximal stage of the test until the 7th shuttle was associated with the distance covered in the Yo-Yo IE1 and HR_{peak}. The 7th shuttle represented an inflection point between an initial phase of steep rise in heart rate values and a second phase in which the rise of the heart rate values is much smaller.

Thus, physical education teachers can consider using the maximal or the submaximal version of the Yo-Yo IE1 Intermittent Tests to assess the fitness levels in adult athletes (Bradley et al., 2011; Krustrup, Randers, Horton, Brito, & Rebelo, 2012; Krustrup et al., 2003). However, to our knowledge, only one study has attempted this in young children (Bendiksen et al., 2013). In fact, the usefulness of submaximal versions of the tests might be particularly relevant in early-age populations as there are limitations associated with maximal testing in children, including musculoskeletal impairments and the need of higher motivational levels (Noonan & Dean, 2000). Indeed, valid submaximal versions might allow evaluations to be applied more regularly since discrimination between high and low performers might be hampered and all children would be able to complete the test accordingly (Bendiksen et al., 2013). Notwithstanding, some disadvantages might rise when using submaximal versions of the Yo-Yo tests. Heart rate responses, for instance, might be influenced by factors such as psychological stress, body temperature and environmental conditions. Also, there is the need for proper measurement equipment, such as heart rate monitors, in order to faithfully obtain submaximal individual heart rate values (Krustrup et al., 2003).

In the present study, large to very large correlations were detected between absolute HR at the 7th shuttle and the distance covered in the Yo-Yo IE1. This means that the 7th shuttle might be an effective submaximal indicator of children's performance on the Yo-Yo IE1. Similarly, HR values, expressed as percentage of individual maximal values, obtained during fixed time points of the test, namely 6 and 9 min, inversely correlated with the distance covered in the Yo-Yo Intermittent Recovery test – Level 1 in adult athletes (Bradley et al., 2011; Krustrup et al., 2003). Bendiksen et al. (2013) tested a submaximal version of Yo-Yo Intermittent Recovery Test – level 1 with children aged 6–10 and found large inverse correlations between $\%HR_{peak}$ and the test performance at 1, 2 and 3 min after the beginning of the test ($r = -0.56$, $r = -0.63$ and $r = -0.61$, respectively). From a practical perspective, it would be preferable to use a specific shuttle run as the criteria point to analyse the submaximal HR, instead of a specific point in time (1, 2, or 3 min). Therefore, we tested the 7th shuttle of the Yo-Yo IE1, which takes place 2.5 min after the beginning of the test, and slightly higher magnitudes of correlation between $\%HR_{peak}$ and the test performance were detected, comparing to those ($r = -0.66$ to -0.73 vs. $r = -0.63$) obtained by Bendiksen et al. (2013).

Interestingly, $\%HR_{peak}$ on the 7th shuttle remained unaltered even though HR_{peak} and absolute HR at the 7th shuttle decreased throughout the year. Since the results show that there was a stable tracking between absolute HR at the 7th shuttle and the performance on the test through time, it is reasonable to conclude that a submaximal version of the Yo-Yo IE1 might provide valuable information regarding the changes in aerobic fitness of children throughout the school year. Though, the lack of effective control of physical activity throughout the year, particularly the content of the physical education classes and recreational sport activities, as well as maturational status stand as limitations of the present study. A high coefficient of variation was found between the three evaluation moments of the Yo-Yo IE1, which might be explained by the temporal distance between the evaluations, maturational development, increasing familiarity with the test and the alterations on the children's physical fitness, as demonstrated by the results. In fact, in the present study, physical fitness parameters, namely sprint and jump performances, might have a growing weight on the Yo-Yo IE1 performance during the course of the year, as presented in Table II; though the correlation coefficients are classified as small. This might indicate that cardiovascular factors are still the most relevant features to determine performance in the Yo-Yo IE1. Thus, we might conclude that in very young children, despite the constant changes of direction during the shuttle runs, peripheral factors, such as lower limb muscle strength, might have trivial interference in the test outcome. These results are distinct from those provided by previous studies conducted in adults, in which a higher contribution of peripheral factors in the test outcome was found (Castagna et al., 2006; Rampinini et al., 2010).

In summary, the present study revealed that performance in the Yo-Yo IE1 test increases during the academic year and that this test can be used to provide important information about the cardiorespiratory fitness level of young school children. The study also revealed that the absolute heart rate measured during a submaximal version of the Yo-Yo IE1 can be used for frequent, non-exhaustive monitoring of changes in cardiorespiratory fitness in children aged 7–10 years. The test was relatively easy to apply in elementary school settings, and all children were able to complete the test. Thus, physical education teachers can consider using the submaximal version of the Yo-Yo IE1 if they intend to evaluate and monitor changes in cardiorespiratory fitness for classes and whole schools throughout the year.

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