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Research article

A Longitudinal Study Investigating the Stability of Anthropometry and Soccer-Specific Endurance in Pubertal High-Level Youth Soccer Players

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Abstract
We investigated the evolution and stability of anthropometric and soccer-specific endurance characteristics of 42 high-level, pubertal soccer players with *high*, *average* and *low* yo-yo intermittent recovery test level 1 (YYIR1) baseline performances over two and four years. The rates of improvement were calculated for each performance group, and intra-class correlations were used to verify short- and long-term stability. The main finding was that after two and four years, the magnitudes of the differences at baseline were reduced, although players with high YYIR1 baseline performance still covered the largest distance (e.g., *low* from 703 m to 2126 m; *high* from 1503 m to 2434 m over four years). Furthermore, the YYIR1 showed a high stability over two years (ICC = 0.76) and a moderate stability over four years (ICC = 0.59), due to large intra-individual differences in YYIR1 performances over time. Anthropometric measures showed very high stability (ICCs between 0.94 to 0.97) over a two-year period, in comparison with a moderate stability (ICCs between 0.57 and 0.75) over four years. These results confirm the moderate-to-high stability of high-intensity running performance in young soccer players, and suggest that the longer the follow-up, the lower the ability to predict player's future potential in running performance. They also show that with growth and maturation, poor performers might only partially catch up their fitter counterparts between 12 and 16 years.

Key words: Football, high-intensity intermittent performance, field test, maturity status, talent development.

Introduction

Over the past two decades, research in the domain of talent identification and development in youth soccer has grown exponentially. Anthropometric, motor coordination and physical performance measures (i.e., explosivity, speed and endurance) have shown to discriminate between successful and less successful youth soccer players (Figueiredo et al., 2009; Vaeyens et al., 2006), and are thought to be predictive for future adult soccer success (Gonaus and Müller, 2012; Le Gall et al., 2010). However, biological maturation confounds these identification and selection processes as late maturing players are systematically excluded as age and sports specialization increases (Malina et al., 2000).

Longitudinal designs are necessary in defining pathways to excellence and maturational status should be considered when evaluating young athletes (Malina et al., 2000; 2004; Vaeyens et al., 2008). Philippaerts et al. (2006) showed that the average age at peak height velocity (13.8 ± 0.8 years) in 33 male youth soccer players was slightly earlier compared to the general population (between 13.8 and 14.2 years). For example, corresponding data for peak oxygen uptake indicated that maximal gains occur at the time of peak height velocity, with continued improvements during late adolescence (Mirwald and Bailey, 1986). Thus, it would seem that around the age of 14 years, maturational status has a critical impact on the development of physiological characteristics in pubertal athletes, and therefore has strong implications for talent identification and development programs (Baxter-Jones et al., 1993).

The Yo-Yo Intermittent Recovery Test Level 1 (YYIR1) is a field test that measures the ability to (quickly) recover between repeated intensive efforts (e.g., sprinting, tackling, jumping) and that maximally stresses the aerobic energy system through intermittent exertion (Krustrup et al., 2003). Previous studies in youth and adult soccer have shown that the Yo-Yo IR1 performance has an adequate to high level of reproducibility (Deprez et al., 2014; Krustrup et al., 2003) and is a valid measure of prolonged, high intensity intermittent running capacity (Sirotic and Coutts, 2007).

When predicting future success at young age, it is important to know whether anthropometrical and physical performances measures are stable in the long-term. This refers to the consistency of the position or rank of individuals in the group relative to others. A review by Beunen and Malina (1988) showed, that in the general population, the stability of physical fitness was moderate (Maia et al., 2003) to good (Maia et al., 2001) throughout adolescence. They also reported that individuals who performed well for their maturity level during adolescence still had a good possibility of performing above average at the age of 30 (Lefevre et al., 1990). In contrast however, within a general sporting population, the best performing players at young age might not remain the best over one year, accounting for poor long-term stability (Abbott and Collins, 2002). Recently, a longitudinal study in 80 pubertal soccer players showed high stability (ICC's: 0.91 to 0.96) for anthropometric measures, moderate stability (ICC's: 0.66 to 0.71) for sprint, speed and explosive leg power and high stability for maximal aerobic speed (ICC: 0.83) (Buchheit and Mendez-Villanueva, 2013).

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However, to date, no such data are available in youth soccer for the intermittent-endurance performance. Therefore, the aim of the present study is to examine the changes in body dimensions and YYIR1 performance in high-level pubertal youth soccer players over two-to-four years. More precisely, we examined whether the baseline values could influence the magnitude of improvement, and whether this improvement is related to maturational status.

Methods

Subjects and study design

A longitudinal study design was conducted over a two- and four-year-period. Subjects were 42 young high-level pubertal soccer players aged between 11 and 16 years from two Belgian professional soccer clubs. All players participated in a high-level training program with minimal 7.5 training hours and 1 game (on Saturday) per week. The two-year follow-up subsample included 21 soccer players, aged 13.2 ± 0.3 y at baseline, who were assessed annually, each time at the end of August (a total of three test moments). In addition, the four-year follow-up subsample included 21 players, aged 12.2 ± 0.3 y at baseline, who were assessed every second year, each time at the end of August (a total of three test moments).

All subjects and their parents or legal representatives were fully informed about the aim and the procedures of the study before giving their written informed consent. The study was carried out in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University Hospital.

Anthropometric measures

Stature (0.1 cm, Harpenden Portable Stadiometer, Holtain, UK), sitting height (0.1 cm, Harpenden sitting height table, Holtain, UK) and body mass (0.1 kg, total body composition analyzer, TANITA BC-420SMA, Japan) were assessed according to manufacturer guidelines. Leg length was calculated by subtracting sitting height from stature. All anthropometric measures were taken by the same investigator to ensure test accuracy and reliability. For height, the intra-class correlation coefficient for test-retest reliability and technical error of measurement (test-retest period of one hour) in 40 adolescents were 1.00 ($p < 0.001$) and 0.49 cm, respectively.

Maturity status

An estimation of maturity status was calculated using equation 3 from Mirwald et al. (2002) for boys. This non-invasive method predicts years from peak height velocity as the maturity offset, based on anthropometric variables (stature, sitting height, weight, leg length). Subsequently, the age at peak height velocity (APHV) is determined as the difference between the chronological age and the maturity offset. According to Mirwald et al. (2002), this equation accurately estimates the APHV within an error of ±1.14 years in 95% of the cases in boys, derived from three longitudinal studies on children who were four years from and three years after peak height velocity (i.e., 13.8 years). Accordingly, the age range for which the equation confidently can be used is between 9.8 and 16.8 years which matches the present age range (11.7-16.7 y).

High intensity intermittent running performance

High intensity intermittent running performance was investigated using the YYIR1. This test was conducted according to the methods described in Krustrup et al. (2003). Participants were instructed to refrain from strenuous exercise for at least 48 hours before the test sessions and to consume their normal pre-training diet before the test session. All tests were conducted on the same indoor venue with standardized environmental conditions. Players completed the YYIR1 test with running shoes and followed a standardized warm-up. To investigate the effect of baseline high intensity intermittent running performance on its changes over the years, players in each subsample were divided into three performance groups according to their YYIR1 performance at baseline: players which YYIR1 performance was below percentile 33 (P33) were classified as ‘*low*’, between P33 and P66, as ‘*average*’ and above P66, as ‘*high*’.

The YYIR1 test has shown good test-retest reliability in 13 adult male experienced soccer players (CV of 4.9 %) and in 16 recreational adults (CV of 8.7 %), respectively (Krustrup et al., 2002; Thomas et al., 2006). Recently, in a non-elite youth soccer population, Deprez and colleagues (2014) reported a CV of 17.3%, 16.7 % and 7.9 % for the YYIR1 test in under-13 (n = 35), under-15 (n = 32) and under-17 (n = 11) age groups, respectively, showing adequate to good reliability. However, of importance in interpreting differences between measures, it is not the CV of a measure that matters, but the magnitude of this ‘noise’ compared with (1) the usually observed changes (signal) and (2) the changes that may have a practical effect (smallest worthwhile difference) (Hopkins, 2004). A measure showing a large CV, but which responds largely to training can actually be more sensitive and useful than a measure with a low CV but poorly responsive to training. The greater the signal-to-noise ratio, the likely greater is the sensitivity of the measure.

Statistical analysis

All statistical analyses were completed using SPSS for windows (version 20.0). First, for each of the two subsamples (two- and four-year follow-up, respectively) differences between the three performance groups (*low*, *average* and *high*) were investigated using multivariate analysis of variance (MANOVA) with performance group as independent and age, maturity offset, stature, body mass and YYIR1 as dependent variables. After running normality tests (Shapiro-Wilk) for all dependent variables in each performance group (in both two- and four-year subsamples), the data passed the assumption of normality (p-values between 0.058 and 0.855) (except for MatOffSet ($p = 0.019$) in the low performance, four-year subsample group). Since MANOVA revealed a significant main effect (Wilks’ Lambda) in both the two- ($F = 15.517$; $p < 0.001$) and four-year subsample ($F = 9.639$; $p < 0.001$), test of between-subject effects were further analyzed for its significance ($p < 0.05$) and Bonferroni *post hoc* tests were performed where appropriate. Also, Cohen's *d* effect sizes were calculated to estimate the magnitude of the differences between each performance group. Thresholds were 0.2, 0.6, 1.2, 2.0 and 4.0 for trivial, small, moderate, large, very large and extremely large, respectively (Hopkins et al., 2008).

For the two- and four-year follow-up subsamples, the changes in stature, body mass and YYIR1 between each test moment for each performance group were expressed as percentages. Also, for each subsample, the rates of improvement (ROI) were calculated for each performance group. A players' rate of improvement (=*attained* ROI) is compared to the rate of improvement of a typical peer (=*benchmark* ROI, based on the mean performance) and is one of the factors considered in determining whether a player (either belonging to the *low*, *average* or *high* group) has made adequate progress to the level of a typical peer. The *target* ROI is defined as the rate of improvement a player should achieve to end up as a typical player. For example, the *low* players' rate of improvement must be greater than the rate of improvement of a typical player (=*target* ROI) in order to "close the gap" and shift to an *average* level of performance (Shapiro, 2008). The ROI was expressed as the number of meters per year (m/y) that players improved from baseline to the end of the present study.

Finally, intra-class correlations (ICC) for maturity offset, stature, body mass and YYIR1 performance were calculated to investigate the two- and four-year stability, respectively. The use of the ICC is the only sensible approach to compute an average correlation between more than two trials, and is calculated as $((SD^2 - \text{typical error}^2) / SD^2)$ where SD is the between-subject standard deviation and the typical error is the within-subject standard deviation (Hopkins, 2000). According to the thresholds of Hopkins et al. (2008) we considered an ICC larger than 0.99 as *extremely high*, between 0.90 and 0.99 as *very high*, between 0.75 and 0.90 as *high*, between 0.50 and 0.75 as *moderate*, between 0.20 and 0.50 as *low* and lower than 0.20 as *very low*.

All results are presented as means (SD) and 95% confidence intervals (CI), and minimal statistical significance was set at $p < 0.05$.

Results

Within the two-year follow-up subsample, there was no significant performance group difference, at each test moment, for chronological age (MANOVA: F = 1.113; p = 0.336) and maturity offset (after post hoc tests, MANOVA: F = 7.824; p = 0.001), reflected by *trivial* to *small* effect sizes (0.00 to 0.24). For stature (MANOVA: F = 15.762; p < 0.001) and body mass (MANOVA: F = 13.302; p < 0.001), at each test moment, *high* players were significant smaller (*large* ES between 1.28 and 1.82) and leaner (*moderate* to *large* ES between 1.19 and 1.81) compared with *low* and *average* players. Also, the YYIR1 performance (MANOVA: F = 42.235; p < 0.001) was significantly different between all performance groups at each test moment (*moderate* to *extremely large* effect sizes) with the following order: *high* > *average* > *low* (Table 1).

Regarding the four-year follow-up subsample, no significant differences were found at each test moment for chronological age (MANOVA: F = 0.726; p = 0.489), maturity offset (MANOVA: F = 2.736; p = 0.074) and stature (MANOVA: F = 3.031; p = 0.057) (*trivial* to *moderate* ES between 0.00 and 1.03). For body mass, *low* players had a higher body mass compared with *average* players at the second (57.5 ± 8.7 kg vs. 48.5 ± 5.7 kg; *large* ES = 1.32) and third test moment (66.7 ± 6.5 kg vs. 60.7 ± 3.0 kg; *large* ES = 1.28). At each test moment, *high* players showed the best YYIR1 performance compared with *low* and *average* players, reflected by *moderate* to *extremely large* ES (between 1.05 and 5.12) (Table 1).

Two-year follow-up analyses revealed similar increases in both stature and body mass in all performance groups (for stature about 7.8 %, for body mass about 27.0 %). The increase in YYIR1 performance in *low* players after the first two-year period was the highest compared with *average* and *high* players (i.e., 97.1 %, 39.1 % and 25.3 %, respectively) (Table 2). Over the overall four-year period, the increase for stature was about 16.0 %, whilst the increase for body mass was about 60.0 % across all performance groups. Also, the increase in YYIR1 performance in *low* players was the highest compared with *average* and *high* players (i.e., 235.7 %, 86.8 % and 62.2 %, respectively) (Table 2).

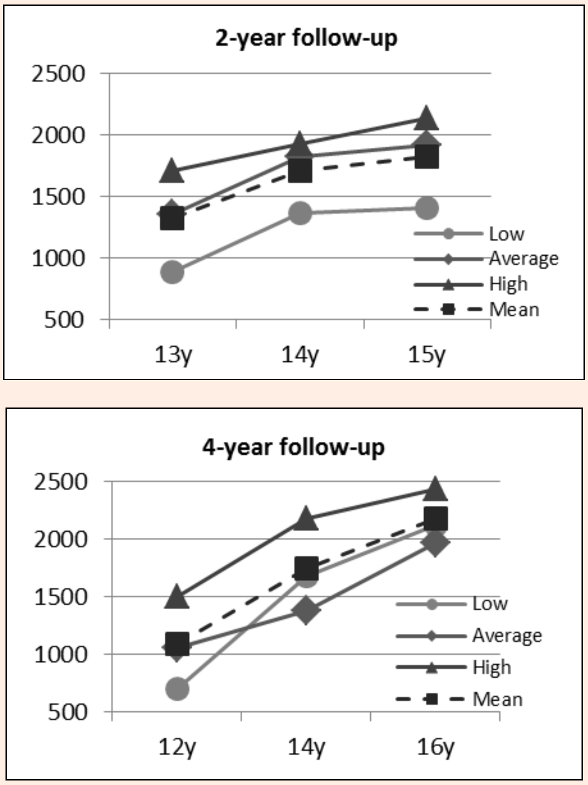

Figure 1. Attained and target (=mean) rate of improvements for the three performance groups (i.e., High, Average and Low) for the 2-year and 4-year follow-up subsample.

Within the two-year follow-up subsample, the benchmark ROI was 252 m/y. Only for *low* players, the attained ROI (263 m/y) was lower compared with the

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Table 1. **Descriptives and differences between low-, average- and high-YYIR1 performance groups and effect by 2- and 4-year follow-up subsamples.**

		Grand mean (n=21)		low (n=7)		average (n=7)		high (n=7)		MANOVA		Cohen's d		
2-year follow-up	**Test**	**Mean (SD)**	**95% CI**	**Mean (SD)**	**95% CI**	**Mean (SD)**	**95% CI**	**Mean (SD)**	**95% CI**	**F-value**	**P-Value**	**Low-Averag**	**Average-High**	**Low-High**
Age (y)	1	13.2 (.3)	± .1	13.2 (.2)	± .1	13.1 (.4)	± .2	13.2 (.2)	± .1	.376	.692	.00	.00	.11
	2	14.2 (.3)	± .1	14.2 (.2)	± .1	14.1 (.4)	± .2	14.2 (.2)	± .1	.392	.682	.24	.24	.12
	3	15.2 (.3)	± .1	15.2 (.2)	± .1	15.2 (.3)	± .1	15.2 (.2)	± .1	.345	.713	.24	.24	.24
Maturity OffSet (y)	1	-.85 (.51)	± .12	-.76 (.46)	± .18	-.60 (.49)	± .20	-1.20 (.43)	± .17	3.287	.061	.16	.09	.11
	2	.14 (.72)	± .16	.27 (.58)	± .23	.44 (.76)	± .30	-.29 (.69)	± .28	2.181	.142	.08	.06	.08
	3	1.17 (.70)	± .16	1.36 (.49)	± .20	1.45 (.85)	± .34	.70 (.52)	± .21	2.849	.084	.07	.03	.03
Stature (cm)	1	157.8 (6.5)	± 1.5	158.4 (3.6)	± 1.4	162.2 (6.5)	± 2.6	152.8 (5.6)	± 2.2	5.432	$.014^{\Sigma}$	.78	1.67	1.28
	2	164.8 (7.5)	± 1.7	165.7 (3.8)	± 1.5	169.8 (7.8)	± 3.1	159.0 (6.4)	± 2.6	5.294	$.016^{\Sigma}$	.72	1.64	1.38
	3	171.1 (6.5)	± 1.5	172.8 (2.9)	± 1.2	174.6 (7.3)	± 2.9	165.7 (5.2)	± 2.1	5.272	$.016^{\Sigma}$	.35	1.52	1.82
Body mass (kg)	1	46.0 (6.8)	± 1.6	48.2 (6.6)	± 2.6	49.3 (5.5)	± 2.2	40.5 (5.0)	± 2.0	4.863	$.020^{\Sigma}$	.20	1.81	1.42
	2	52.7 (8.7)	± 2.0	54.6 (7.6)	± 3.0	57.0 (8.0)	± 3.2	46.2 (7.6)	± 3.0	3.592	$.049^{\Sigma}$	.33	1.50	1.19
	3	59.3 (8.8)	± 2.0	62.5 (7.7)	± 3.1	63.5 (7.9)	± 3.2	52.0 (6.3)	± 2.5	5.312	$.015^{\Sigma}$	.14	1.74	1.61
YYIR1 (m)	1	1319 (366)	± 83	886 (114)	± 46	1357 (100)	± 40	1714 (145)	± 58	82.471	$<.001^{\#}$	4.74	3.10	6.86
	2	1705 (371)	± 85	1366 (360)	± 144	1823 (231)	± 92	1926 (265)	± 106	7.386	$.005^{\#}$	1.63	.45	1.91
	3	1823 (427)	±97	1411 (252)	± 101	1920 (414)	± 166	2137 (220)	± 88	10.296	$.001^{\#}$	1.60	.71	3.32

		Grand mean (n=21)		low (=7)		average (n=7)		high (n=7)		MANOVA		Cohen's d		
4-year follow-up	**Test**	**Mean (SD)**	**95% CI**	**Mean (SD)**	**95% CI**	**Mean (SD)**	**95% CI**	**Mean (SD)**	**95% CI**	**F-value**	**P-value**	**Low-Averag**	**Average-High**	**Low-High**
Age (y)	1	12.2 (.3)	± .1	12.3 (.3)	± .2	12.2 (.4)	± .3	12.2 (.2)	± .2	.267	.769	.31	.00	.42
	2	14.2 (.3)	± .1	14.3 (.3)	± .2	14.2 (.4)	± .3	14.2 (.2)	± .2	.244	.786	.31	.00	.42
	3	16.2 (.3)	± .1	16.3 (.3)	± .2	16.3 (.4)	± .3	16.1 (.3)	± .2	.462	.638	.00	.61	.72
Maturity OffSet (y)	1	-1.72 (.34)	± .15	-1.54 (.33)	± .24	-1.83 (.38)	± .28	-1.80 (.28)	± .21	1.553	.239	.88	.10	.92
	2	.28 (.61)	± .26	.57 (.50)	± .37	.04 (.83)	± .61	.23 (.36)	± .27	1.388	.275	.84	.32	.84
	3	2.14 (.47)	± .20	2.28 (.23)	± .17	2.11 (.63)	± .47	2.04 (.52)	± .39	.431	.657	.39	.13	.64
Stature (cm)	1	150.7 (3.6)	± 1.5	152.5 (1.8)	± 1.3	149.9 (3.4)	± 2.5	149.7 (4.8)	± 3.6	1.408	.270	1.03	.05	.83
	2	165.2 (5.2)	± 2.2	167.8 (4.6)	± 3.4	163.3 (5.6)	± 4.2	164.5 (4.9)	± 3.6	1.492	.251	.95	.25	.75
	3	174.6 (3.9)	± 1.7	175.8 (4.1)	± 3.0	174.3 (2.8)	± 2.1	173.8 (4.8)	± 3.6	.497	.647	.46	.14	.48
Body mass (kg)	1	39.5 (4.4)	± 1.9	42.3 (5.0)	± 3.7	37.9 (4.2)	± 3.7	38.4 (2.8)	± 2.1	2.375	.121	1.03	.15	1.04
	2	52.3 (7.2)	± 3.1	57.5 (8.7)	± 6.4	48.5 (5.7)	± 6.4	50.7 (3.6)	± 2.7	3.781	$.043^{\infty}$	1.32	1.10	.15
	3	62.9 (5.1)	± 2.2	66.7 (6.5)	± 4.8	60.7 (3.0)	± 4.8	61.2 (3.1)	± 2.3	3.732	$.044^{\infty}$	1.28	0.18	1.17
YYIR1 (m)	1	1090 (367)	± 157	703 (224)	± 166	1063 (128)	± 95	1503 (83)	± 61	45.947	$<.001^{\#}$	2.13	4.41	5.12
	2	1749 (406)	± 174	1686 (194)	± 144	1384 (311)	± 230	2177 (202)	± 150	19.281	$<.001^{\Sigma}$	1.26	3.27	2.68
	3	2175 (338)	± 145	2126 (373)	± 276	1966 (218)	± 161	2434 (248)	± 184	4.801	$.021^{\Sigma}$	.57	2.17	1.05

SD=standard deviation; CI=confidence interval; $^{\#}$ significant differences between all performance groups; $^{\infty}$ Low is different from Average; $^{\Sigma}$ high is different from low and average

target ROI (469 m/y). For *average* and *high* players, the attained ROI's (252 and 212 m/y, respectively) were larger compared with the target ROI's (233 and 55 m/y, respectively) (Table 3, Figure 1). For the four-year follow-up subsample, the benchmark ROI was 271 m/y. The attained ROI's for *low* (356 m/y) and *average* (226 m/y) players were just below the target ROI's (368 and 278 m/y, respectively). For *high* players, the attained ROI (233 m/y) was larger compared with the target ROI (168 m/y) (Table 3, Figure 1).

Two-year stability analyses revealed *very high* ICC's for stature, body mass and

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Table 2. Percent change and correlations between the three test moments for stature, body mass and YYIR1 within all performance groups by 2- and 4-year follow-up subsamples.

		low (n=7)			average (n=7)			high (n=7)		
2-year follow-up	**Test**	**Mean**	**SD**	**95% CI**	**Mean**	**SD**	**95% CI**	**Mean**	**SD**	**95% CI**
Stature (%)	1-2	4.3	1.4	± .6	4.2	1.2	± .5	4.2	1.5	± .6
	2-3	3.4	1.5	± .6	3.4	1.8	± .7	3.4	1.8	±0.7
	1-3	7.9	2.6	± 1.0	7.8	2.5	± 1.0	7.8	3.0	± 1.2
Body mass (%)	1-2	14.1	6.3	± 2.5	14.1	5.2	± 2.0	13.3	5.4	± 2.2
	2-3	12.0	5.2	± 2.1	12.2	5.3	± 2.0	11.7	7.2	± 2.9
	1-3	27.8	8.9	± 3.6	28.0	9.2	± 3.5	26.7	11.1	± 4.4
YYIR1 (%)	1-2	70.6	75.4	± 30.2	17.2	21.3	± 8.2	11.7	19.2	± 7.7
	2-3	18.5	30.0	± 12.0	22.2	25.9	± 10.0	15.2	23.0	± 9.2
	1-3	97.1	91.7	± 36.7	39.1	23.8	± 9.2	25.3	14.0	± 5.6
		low (n=7)			**average (n=7)**			**high (n=7)**		
4-year follow-up	**Test**	**Mean**	**SD**	**95% CI**	**Mean**	**SD**	**95% CI**	**Mean**	**SD**	**95% CI**
Stature (%)	1-2	10.0	2.1	± 1.6	9.0	2.3	± 1.7	9.9	2.7	± 2.0
	2-3	4.8	3.3	± 2.4	6.8	2.9	± 2.2	5.7	2.2	± 1.6
	1-3	15.3	3.2	± 2.4	16.4	2.7	± 2.0	16.2	2.7	± 2.0
Body mass (%)	1-2	35.7	9.6	± 7.1	28.3	7.7	± 5.7	32.2	8.4	± 6.2
	2-3	17.3	12.5	± 9.3	26.0	9.6	± 7.1	21.2	8.6	± 6.4
	1-3	58.8	16.4	± 12.2	61.2	10.2	± 7.6	59.9	12.2	± 9.0
YYIR1 (%)	1-2	170.7	118.1	± 87.5	30.3	27.5	± 20.4	45.2	15.3	± 11.3
	2-3	25.7	13.3	± 9.9	47.2	30.6	± 22.7	11.9	6.2	± 4.6
	1-3	235.7	132.7	± 98.3	86.8	28.4	± 21.0	62.2	15.7	± 11.6

SD=standard deviation; CI=confidence interval.

maturity offset, and *low*-to-*moderate* ICC's for the YYIR1 performance in each performance group (Table 4). Overall, when analyzing the total subsample, *high*-to-*very high* ICCs for all variables were found. Within the four-year subsample, stability analyses for maturity offset, stature and body mass revealed *low* to *moderate* ICC's in all performance groups, except for body mass in *average* players. For YYIR1 performance, *low* ICC's were reported for all performance groups. Generally, *moderate* ICC's for all variables after a four-year period were reported (Table 4).

Discussion

We investigated the evolution and stability of anthropometry and YYIR1-performance of 42 high-level, pubertal soccer players with *high*, *average* and *low* YYIR1 baseline performances over two and four years. Also, two- and four-year stability of anthropometrical characteristics and YYIR1 performance was examined. The main finding was that after two and four years, the magnitudes of the differences at baseline were reduced, although players with high YYIR1 baseline performance still covered the highest distance up until 16 years. Furthermore, the YYIR1 showed a high stability over two years (ICC = 0.76) and a moderate stability over four years (ICC = 0.59). Anthropometry showed very high stability (ICCs between 0.94 to 0.97) over a two-year period, in contrast to a moderate stability (ICCs between 0.57 and 0.75) over four years. These findings indicate that YYIR1 performance together with anthropometrical characteristics should be evaluated over time, with emphasis on individual development (and comparison with benchmarks).

The present YYIR1 results showed the high level of intermittent-endurance capacity when compared with 16 elite youth soccer players, aged 17 years (2150 ± 327

Table 3. Rates of improvements (ROI) for YYIR1 of the different performance groups over a 2- and 4-year period.

2-year follow-up	**PG**	**Formula**	**ROI**	**Linear Regression**
Benchmark ROI	Mean	(1823m – 1319m) / 2	252 m/y	y = 252 x + 1112
Target ROI	Low	(1823m – 886m) /2	469 m/y	
	Average	(1823m – 1357m) / 2	233 m/y	
	High	(1823m – 1714m) / 2	55 m/y	
Attained ROI	Low	(1411m – 886m) /2	212 m/y	y = 263 x + 696
	Average	(1920m – 1357m) / 2	252 m/y	y = 252 x + 1112
	High	(2137m – 1714m) /2	263 m/y	y = 212 x + 1503
4-year follow-up	**PG**	**Formula**	**ROI**	**Linear Regression**
Benchmark ROI	Mean	(2175m – 1090m) / 4	271 m/y	y = 543 x + 586
Target ROI	Low	(2175m – 703m) / 4	368 m/y	
	Average	(2175m – 1063m) / 4	278 m/y	
	High	(2175m – 1503m) / 4	168 m/y	
Attained ROI	Low	(2126m – 703m) / 4	356 m/y	y = 712 x + 82
	Average	(1966m – 1063m) / 4	226 m/y	y = 452 x + 568
	High	(2434m – 1503m) / 4	233 m/y	y = 466 x + 1107

PG = Performance group; ROI = Rate of improvement; m/y = meter per year

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Table 4. **Intra-class correlations for maturity offset, stature, body mass and YYIR1 by 2- and 4-year intervals.**

	Overall (n=21)		Low (n=7)		Average (n=7)		high(n=7)	
2y stability	**ICC**	**95% CI**	**ICC**	**95% CI**	**ICC**	**95% CI**	**ICC**	**95% CI**
Maturity OffSet	.97	.95 - .98	.97	.94 - .98	.97	.93 - .98	.97	.54 - .86
Stature	.94	.91 - .96	.92	.86 - .96	.95	.91 - .98	.93	.86 - .97
Body mass	.94	.92 - .96	.95	.90 - .98	.93	.88 - .97	.94	.88 - .97
YYIR1	.76	.68 - .84	.43	.18 - .67	.68	.48 - .82	.73	.54 - .86
	Overall (n=21)		**Low (n=7)**		**Average (n=7)**		**High (n=7)**	
4y stability	**ICC**	**95% CI**	**ICC**	**95% CI**	**ICC**	**95% CI**	**ICC**	**95% CI**
Maturity OffSet	.66	.44 - .83	.59	.12 - .90	.74	.34 - .94	.48	.00 - .86
Stature	.57	.32 - .78	.27	-.17 - .71	.54	.07 - .89	.70	.28 - .93
Body mass	.75	.57 - .88	.73	.32 - .94	.81	.47 - .96	-.38	.09 - .82
YYIR1	.59	.34 - .79	.38	-.09 - .83	.36	-.11 - .82	-.44	.04 - .87

m; Rampinini et al., 2008), Croatian elite youth soccer players (U13: 933 ± 241 m, U17: 1581 ± 390 m; Markovic and Mikulic, 2011), and 21 youth soccer players from San Marino, aged 14 years (842 ± 352 m; Castagna et al., 2009). A reasonable explanation could be that the present sample of youth soccer players is subjected to training stimuli that focus greatly on the development of intermittent-endurance capacity therefore explaining the high level of YYIR1 performances. Consequently, the present data could serve as reference values or standards for other youth soccer samples in high-level soccer development programs.

Considering the differences in YYIR1 results between the three performance groups at baseline, these large discrepancies in performance decreased over time, especially between the *low* and *high* performance groups. For example, the difference at baseline between *low* and *high* was 800 m (ES = 5.12) corresponding to 20 YYIR1 running bouts, whilst four years later, the difference decreased to 308 m (ES = 1.05), which corresponds to approximately 8 running bouts. A similar trend was noticeable over a two-year period although less distinct: the difference in YYIR1 performance between *low* and *high* at baseline was 828 m (ES = 6.86) and diminished to 726 m (ES = 3.32), corresponding to approximately 21 and 18 running bouts, respectively. Also, the higher performance groups continued to perform better than the lower performance groups within each subsample. Indeed, within the two-year follow-up period, the highest baseline performance group continued to improve their YYIR1 performance with a higher rate compared with the lowest baseline performance group (263 m/y vs. 212 m/y, respectively). In contrast, in the four-year follow-up period, the lowest baseline performance group progressed with a higher rate compared to the highest baseline performance group (356 m/y vs. 233 m/y, respectively).

These results indicate that during the pubertal years (i.e., 11 to 16 y), high-level soccer players with a relatively low intermittent-endurance capacity have the potential to improve their YYIR1 performance up to the average level of their peers. The greater improvement of players from the lowest baseline performance group (up to 235.7 % over a four-year period) compared with average (up to 86.8 %) and high (up to 62.2 %) performance groups, might reveal their potential to eventually catch-up or close the gap with the better performers on the long term although no longitudinal data were available after the age of 16 years. Moreover, Hill-Haas and colleagues (2009) investigated the effect of implementing small-sided game versus mixed generic training on several physiological parameters during seven weeks in pre-season in 19 elite youth soccer players, aged 14 years. Both training groups improved their YYIR1 performance after seven weeks: the small-sided training group ran 254 m further (from 1488 m to 1742 m; + 16.9 %), whilst the mixed generic training group improved their performance with 387 m (from 1764 m to 2151 m; + 21.7 %). The latter results showed that both training groups were capable to quickly improve their aerobic fitness level, although baseline and outcome differences between both training groups were still apparent.

The highest improvement in both subsamples occurred around the timing of peak height velocity (when players moved from pre- to post-peak height velocity) (Table 3). This is in accordance with the results of a longitudinal study by Philippaerts et al. (2006) where the highest increase in cardiorespiratory endurance coincident with the timing of peak height velocity. An investigation by Malina & Bailey (1986) already indicated that maximal gains in peak oxygen occurred around peak height velocity timing and that continued improvement was observed during the late adolescence. Future research should extend this longitudinal approach into young adulthood (after 16 years) to examine if low performers eventually catch-up with their initially higher performing counterparts.

The differences in YYIR1 performances at baseline between low and high performance groups seem not to be influenced by body size and maturational status since in both subsamples, the highest performers were the smallest, leanest and furthest away from peak height velocity (i.e., in the two-year period: 152.8 cm, 40.5 kg and -1.20 y, respectively) compared with the lowest performers (i.e., 158.4 cm, 48.2 kg and -0.76 y, respectively). A related study in 143 Portuguese young soccer players (11-14 years) showed that body mass was disadvantageous for the YYIR1 performance (Figueiredo et al., 2011). Therefore, anthropometrical characteristics and maturational status cannot explain these baseline differences, although several studies have shown that soccer players with increased body size dimensions and biological maturity perform better in speed, power and strength, especially during pubertal years (Carling et al., 2009; Figueiredo et al., 2009; Malina et al., 2004; Vaeyens et al., 2006).

Moreover, another study investigating anthropometrical characteristics, skeletal age and physiological parameters among 159 Portuguese elite youth soccer players, aged 11-14 years, showed that late maturing soccer players had a higher intermittent endurance compared with early maturing peers (Figueiredo et al., 2009). Also, a study by Deprez et al. (2012) reported that the maturational status had a relatively small influence on the YYIR1, since selection procedures focus on the formation of homogenous groups in terms of anthropometry and biological maturation. Additionally, a study by Segers et al. (2008) stated that running style plays an important role in the running economy of late maturing soccer players, and therefore the latter can succeed in keeping up with early maturing soccer players. Other possible factors including training volume, experience, quality of training and field position might influence the large range of YYIR1 performance in each subsample and the lack of this information on these potentially confounding variables is a limitation of the present study. Nevertheless, all players in the present study performed the same training program.

The present results revealed high stability (ICC's: 0.90-0.94) of anthropometrical characteristics and maturational status over a two-year period. In contrast however, a poorer, although high (ICC = 0.76) stability in YYIR1 was apparent in the latter subsample despite similar changes in anthropometrical characteristics and maturational status. In contrast with the very high stability of anthropometrical characteristics and maturational status over a two-year period, moderate stability in both anthropometry and maturational status was observed over the long-term (four-year period). This result possibly indicates the large inter-individual differences in growth and maturation of pubertal children (Malina et al., 1994), despite the homogeneity in terms of anthropometry and maturational status in elite youth soccer players around peak height velocity (Deprez et al., 2012). Indeed, additional analyses revealed that 47.6 % and 28.2 % of the players were moving to a higher or lower percentile group on the long-term for stature and maturational status, respectively. Additionally, 47.6 % of the players were moving to a higher or lower YYIR1 performance group, also resulting in moderate stability over a four-year period (ICC = 0.59). For example, 12-year-old players with the highest high-intensity intermittent-performance might not remain the best when they reach the age of 16 years. This point is in agreement with poor long-term stability observed in a general sporting population over a year (Abbott and Collins, 2002). Indeed, a review by Vaeyens et al. (2008) discussed the unstable non-linear development of performance determinants, making one-shot long-term predictions unreliable. The fact that some players were able to greatly improve their YYIR1 performance (e.g., one player went from 1280 m to 2360 m over two years), lends support to individual interventions to develop high-intensity intermittent running performance.

The present study has its limitations. First, we found a large variation in rank scores of the players regarding anthropometrical characteristics and YYIR1 performance over a four-year period. However, within such a limited group of players (n = 7), small changes in ranking are responsible for large changes in ICCs. Therefore, we expected the overall ICCs to be larger than within each performance group, which reflects more the reality of a young soccer team which includes players of different performance levels at the same time. Furthermore, longitudinal studies on a larger sample size and after 16 years of age, accounting for individual training contents are warranted to draw definite conclusions. Also, caution is warranted when using maturity offset as an estimation of biological maturation. According to Mirwald et al. (2002), the equation is appropriate for children between 9.8 and 16.8 years, although it appears that the estimation is more accurate in the middle of this range. Since players in the present study matched the latter age-range and players were only compared within the same age group, these limitations of the predictive equation were restrained and the use of maturity offset justified (Deprez et al., 2012). Also, recent studies showed poor to moderate agreement between invasive and non-invasive methods to predict maturational status (Malina et al., 2012; 2013). The equation to estimate maturity offset emerged from longitudinal studies from Canada and Belgium and many users tend to ignore the magnitude of standard error of estimation and the potential variation of agreements between estimated and real values at ages long before PHV and long after PHV. This limitation should be considered when considering future research in this area. Moreover, further research is necessary to validate the maturity offset method in a young soccer population.

Conclusion

In the present study, we attempted to identify developmental pathways for maturational status, anthropometrical characteristics and high-intensity intermittent-running performance in homogenous groups of players according to their performance at baseline. Although the magnitudes of the differences at baseline were reduced after two and four years, players with high initial YYIR1 performance still covered the highest distance. Furthermore, the YYIR1 showed a high stability over two years and a moderate stability over four years, suggesting that the longer the follow-up, the lower the ability to predict player's future potential in running performance (Vaeyens et al., 2008). Our results also show that with growth and maturation, poor performers might only partially catch up their fitter counterparts between 12 and 16 years.

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Key points

- Young, high-level soccer players with a relatively low intermittent-endurance capacity are capable to catch up with their better performing peers after four years.
- Individual development and improvements of anthropometric and physical characteristics should be considered when evaluating young soccer players.

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