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Maturation and Bio-Banding in Youth Soccer Players: Insights from Turkish Male Academy across U-10 to U-15 Age

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ABSTRACT

Soccer academies are vital in identifying and nurturing young talent for senior-level competition. Relative age and biological maturation influence player performance and selection in youth soccer. While often grouped by Chronological Age (CA), variations within a CA category can lead to differences in maturation, with the Relative Age Effect (RAE) favoring older players' performance. Maturation, marked by physical and cognitive development, can significantly affect performance. Therefore, this study examined the interrelations between relative age, maturation status, and bio-banding in youth soccer players in U10 to U15 age cohorts. This study examined 60 male soccer players aged 10 to 15 (mean ± standard deviation; age: 12.6 ± 1.7 years; Weight: 49 ± 15.1 kg; Height: 157.2 ± 12.8 cm; sitting height: 69.7 ± 6.7 cm), assessing anthropometric measurements, maturation status, and physical performance. Players' physical attributes and performance levels were influenced by their maturation status rather than their relative age, with maturation-related disparities in strength and jump performance observed among age groups. Bio-banding, a strategy categorizing players by maturation status, created more equitable groups with homogenized physical attributes and performance. Early-maturing players showed advantages in physical attributes, while late-maturing players displayed enhanced leadership and self-confidence. Understanding maturation status is crucial for accurate performance assessment and equitable player grouping in youth soccer. This study underscores the significance of considering maturation status as a distinct determinant in evaluating young soccer players.

Keywords: Talent identification, Motor competence, Anthropometric, Soccer players, Physical performance, Körperkoördinations Test für Kinder

INTRODUCTION

Soccer academies constitute a pivotal trajectory in the continuum of youth player development, serving a vital purpose in discerning and nurturing proficient individuals for eventual participation in the senior echelons of competition (1). Relative age and biological maturation significantly influence player performance and selection in youth soccer (2). Relative age and biological maturation represent discrete constructs characterized by autonomous existence and operational independence (3, 4). Soccer practitioners routinely aggregate players according to their Chronological Age (CA), using designated groupings with specific cut-off dates. Such annual-age classifications, prevalently employed in youth sports, are designed to engender an environment that aligns with the developmental stage of participants, thereby fostering equitable opportunities and just competition (5). Nevertheless, it is noteworthy that CA can vary up to a single year within a given CA category (6).

Consequently, senior players born earlier within a CA cohort show more advanced physical and cognitive maturation than their junior counterparts born later within the same CA cohort (7). This discernible disparity is due to adopting categorical and chronologically defined (bi)annual stratifications in soccer academies, denoted by nomenclature such as U10, U11, U12, and so forth (8). This convention engenders a potential temporal separation of nearly twelve months between individuals within identical age classifications (9). The relative age effect (RAE) explains this phenomenon, characterised by a higher propensity for players born during the initial junctures of the selection year (e.g., birth quartiles BQ1 and BQ2) securing placement in talent development trajectories (~38–40% and ~24–30%, respectively) than their counterparts born during the latter phases of the year (BQ3: ~15–21% and BQ4: ~13–16%, respectively) (10).

Biological maturation denotes the intricate progression toward an advanced physiological state, exhibiting disparities in magnitude (extent of alteration), timing (commencement of transformation), and tempo (rate of transition) across distinct bodily systems and among individuals (11). In cohorts showing an inclination toward competitive engagement in team sports, a minority attains higher athletic proficiency (12). Numerous studies have underscored the presence of biological heterogeneity among young athletes, significantly affecting talent discernment and athletic qualification (13-15). From a somatic perspective, individuals who display an accelerated maturation trajectory, regardless of gender, demonstrate an augmented linear dimension and amplified bodily mass compared to their counterparts who share the same chronological age (2, 16). This physiological endowment confers a pronounced competitive edge, particularly in disciplines typified by vigorous physical engagements and collisions. This inter-individual disparity is most conspicuously evident during the ages 11 to 16 (17). Notably, the phase of adolescence emerges as the temporal domain wherein these differences attain their zenith, with the interval spanning 13 to 16 years of age emerging as the epoch of greatest heterogeneity (18). While chronological age remains foreseeable and amenable to straightforward evaluation, determining biological age presents a greater challenge (19). The preeminent approach for appraising maturation involves skeletal age assessment, yet the exigencies of cost and the necessity for adept radiographers proficient in this technique engender its limited practicality.

Alternative methodologies are frequently employed to address these limitations. Mirwald et al. introduced a prognostic model grounded in the theoretical framework of discrepant growth velocities between the lower limbs and the torso (20). This model yields the percentage of predicted adult height (%PAH), which can be computed at distinct junctures in childhood and adolescence, thereby facilitating the assessment of the maturational status of juvenile athletes. Termed Bio-Banding (BB), this methodology is a non-invasive gauge of biological maturation (21). The fundamental objective of the bio-banding approach is to mitigate the impact of inter-individual variances in maturation, thereby allowing both early and late-maturing youths to engage in participation and competition under conditions more attuned to their developmental stage (22). Therefore, the present study explored the relationship between relative age, maturation status, and bio-banding in soccer participants spanning the U10 to U15 age cohorts. It was hypothesised that heightened maturation status, as opposed to advancement in relative age, would align with enhanced physical performance levels and gross motor proficiencies.

MATERIALS AND METHODS

Participants

The study encompassed 60 male soccer players (mean ± standard deviation; age: 12.6 ± 1.7 years; Weight: 49 ± 15.1 kg; Height: 157.2 ± 12.8 cm; sitting height: 69.7 ± 6.7 cm), spanning the U-10 to U-15 age categories, exclusively affiliated with a singular sports club in Istanbul, Turkey. The data collection phase transpired from February through March in the regular season of 2022. Figure 1 illustrates the schematic of the study design process. All participants, their legal guardians and the club association were provided with written information explaining the research objectives, procedures, potential advantages, and the right to withdraw from the study at any time, with written assent/consent obtained from each participant and their respective parents or guardians before participation. Participants with pre-existing injuries or contraindications to basic anthropometric measurements were deliberately excluded. The Ethics Committee for Scientific Research at Istanbul Gedik University granted ethical approval for the study, which adhered to the Declaration of Helsinki.

Protocol

Standing height, sitting height, and body mass were measured using standard procedures. Standing and sitting heights were measured using a portable stadiometer (Seca Road Rod, Seca Corporation, Hanover, MD). During both anthropometric assessments, participants were instructed to stand in a normal posture with weight equally distributed between feet. Subsequently, the leg length of each participant was calculated by subtracting their sitting height from their standing height (23, 24).

Chronological age was determined by calculating the difference between the participant's date of birth and observation date. This calculation led to the subsequent classification of participants into discrete one-year age cohorts. Each delineated age group spanned a complete calendar year and was demarcated as follows: 10 years (10.00 - 10.99), 11 years (11.00 - 11.99), 12 years (12.00 - 12.99), 13 years (13.00 - 13.99), 14 years (14.00 - 14.99), and 15 years (15.00 - 15.99) (2).

The determination of age at peak height velocity (APHV) for the participants was executed by deducting the maturity offset from their chronological age at the juncture of measurement. The computation of maturity offset involved the application of a well-established, non-invasive equation (20), which leveraged anthropometric variables and age to extrapolate the temporal deviation in years from the peak height velocity (PHV) epoch. A negative (–) maturity offset denoted the temporal difference in years preceding PHV, while a positive (+) maturity offset signified the temporal difference in years following PHV. The categorisation of participants into maturity groups was delineated by establishing the midpoint of each range as a whole calendar year. The maturity classifications were outlined as follows: −4 = (−4.50, −3.51), −3 = (−3.50, −2.51), −2 = (−2.50, −1.51), −1 = (−1.50, −0.51), 0 = (−0.50, 0.49), 1 = (0.50, 1.49), 2 = (1.50, 2.49), and 3 = (2.50, 3.49). The gender-specific equations for boys and girls are as follows:

Boys: Maturity offset = –9.236 + 0.0002708 (leg length x sitting height) — 0.001663 (age x leg length) + 0.007216 (age x sitting height) + 0.02292 (weight: height).

Girls: Maturity offset = –9.376 + 0.0001882 (leg length x sitting height) + 0.0022 (age x leg length) + 0.005841 (age x sitting height) — 0.002658 (age x weight) + 0.07693 (weight: height).

The delineation of birthdate distribution rested upon the birth date of each soccer player juxtaposed with the cut-off date associated with their corresponding year group, notably the 1st of January. As a result, the beginning of the selection year was assigned to January, while December was allocated as its culmination. By aggregating the birth month of individual players, the formation of birth quarters (Q) was achieved, giving rise to the demarcation of four distinct birth quartiles: Q1 (1st of January to 31st of March), Q2 (1st of April to 30th of June), Q3 (1st of July to 30th of September), and Q4 (1st of October to 31st of December).

The evaluation of flexibility encompassed the implementation of the conventional sit-and-reach test, wherein the demarcation for foot placement was established at a fixed distance of 23 cm. Participants were required to remove their footwear and execute three successive trials of the sit-and-reach assessment. The objective of each trial was to exert maximal effort in extending the slide to its furthest point on the sit-and-reach box while maintaining leg extension. The best outcome for each participant was used for the statistical analysis (25).

The leg strength was assessed using a back and lift dynamometer (Takei Scientific Instruments Co., Ltd., Niigata, Japan). Participants were instructed to exert consistent force against the applied weight while sustaining the even positioning of their feet upon the dynamometer platform. Each participant undertook two successive trials, with the highest performance used for further analysis.

Vertical jump height was measured using a digital meter (Takei Scientific Instruments Co., Ltd., Niigata, Japan). Participants performed a bilateral vertical jump, starting from a stationary erect stance, without any countermovement or employment of their upper limbs. Two vertical jumps were performed, with the highest jump used for statistical analysis (26).

The zigzag agility tests were conducted on a soccer grass pitch with and without a ball. Each test was undertaken twice, with an inter-trial interval of 2 minutes provided for recovery. The time was recorded for each trial with and without ball involvement, with the best performance used for subsequent analysis. The configuration of the zigzag agility tests course entailed the arrangement of four consecutive 5-meter segments oriented at angles of 100 degrees. Time was measured using electronic Photocell timing gates (27).

Two successive 20-meter sprints were executed in an outdoor soccer court setting, with a 2-minute rest allowed for recovery. Employing a stationary commencement posture, participants initiated the sprints, maintaining a position where the foremost foot was situated one meter rearward from the inaugural timing gate. Photocell timing gates were used to measure sprint time, with the best sprint times used for further analyses (2).

The general gross motor coordination assessment was conducted using the KTK3, an adapted edition of the Körperkoordinationstest für Kinder (KTK) originally formulated by Kiphard and Schilling (28). The KTK3 regimen encompasses a triad of evaluative components. In the initial segment, designated as jumping sideways (JS), participants were instructed to perform bilateral jumps over a wooden slat for 15 seconds. The cumulative score was derived from the summation of jump instances across both trials. The subsequent evaluative phase, termed moving sideways (MS), necessitated participants to traverse a linear trajectory while manipulating two wooden platforms within a 20-second interval. The composite score encompassed the frequency of wooden platform placements and instances of stepping on displaced wooden platforms during the paired trials. The final element of the KTK3 evaluation, labelled as balancing backwards (BB), encompassed three trials on balance beams of diminishing width (6.0 cm, 4.5 cm, and 3.0 cm). The cumulative count of steps executed by participants was recorded, with an upper limit of 72 steps (equivalent to 8 steps per trial on each balance beam). To ascertain the motor coefficients (MQ), the cumulative performance across these three subtests was used to classify participants into distinct categories of coordinative development. These classifications encompass high coordination, good coordination, normal coordination, coordination disorder, and coordination insufficiency. The age and gender-specific motor quotient (MQ) was calculated using normative data from a cohort of 1128 typically developing German children, as established by Kiphard and Schilling (1974).

Statistical Analysis

Descriptive statistics, including mean and standard deviations and 95% confidence intervals, were calculated for gender, age, height, and weight. The data normal distribution was examined and confirmed using the Shapiro-Wilk test. Discrete one-way analysis of covariance (ANCOVA) assessments was conducted to examine differences across age groups, birth quartiles, and maturity classifications with age as a covariate and Bonferroni post hoc analyses to identify significant differences between groups. The quantification of players within each birth quartile (BQ1–4) and maturity classification (early, on-time, late) was performed through frequency counts. The relationships between relative age and the percentage of predicted age at peak height velocity (PAH), with physical performance and motor coordination, were explored by Pearson's correlation coefficients. The interpretation of correlation magnitudes adhered to established guidelines, categorising coefficients into ranges of <0.2 (absence of relationship), 0.2–0.45 (weak), 0.45–0.7 (moderate), and >0.7 (strong). All sample scores were aggregated for motor quotient analysis by summating raw scores derived from individual subtests. The cumulative motor quotient (MQsum) was computed as follows: MQsum = WB + SJ + MS, with WB, SJ, and MS denoting raw data from Walking Backward, Jumping Sideways, and Moving Sideways, respectively. All data were analysed using IBM SPSS for Windows (version 26, Chicago, Illinois). Also, The determination of an appropriate sample size for a one-way analysis was meticulously undertaken through the utilization of G*Power software (v3.1.9.2, Universität Kiel, Düsseldorf, Germany). The software validation yielded a consensus that a sample size of 60 is considered satisfactory for the intended analysis.

Results

The distribution of birthdates and maturity status within each quartile is visually presented in Figures 1 and 2, respectively. Descriptive statistics of height, weight, Predicted Adult Height (PAH), percentage of Predicted Adult Height (%PAH), and performance parameters, including sit-and-reach, leg strength, countermovement vertical (CMJ) jump height, slalom performance with and without the ball, 20-meter sprint test with and without the ball, and the Körperkoordination Test für Kinder are detailed in Table 1. Outcomes of analysis of variance (ANOVA) indicated that the older age group participants exhibited statistically significant elevations in anthropometric measurements and physical performance test results relative to their younger counterparts ($p < 0.05$; Table 2). The adjusted means encompassing height, weight, PAH, %PAH, and performance parameters, including sit-and-reach, leg strength, CMJ jump height, slalom performance with and without the ball, 20-meter sprint test with and without the ball, and Körperkoordination Test für Kinder, stratified by birth quartiles, are presented in Table 3. Statistical analysis revealed no statistically significant variations among birth quartiles for the measured variables ($p > 0.05$). Height, weight, and performance parameter-adjusted means for each maturity classification are presented in Table 4. Early-maturing individuals exhibited significantly elevated height and weight relative to both on-time and late-maturing peers ($p < 0.05$). Moreover, performance for both early and on-time maturing individuals demonstrated significantly greater physical performance compared to their late-maturing counterparts ($p < 0.05$).

Table 5 shows the relationships between relative age, maturity, and performance. A moderate correlation emerged between maturity and physical performance ($r = 0.416$; $p < 0.05$). However, no significant associations were observed between birth distribution, maturity, and motor coordination ($p > 0.05$). Furthermore, no relationship was found between relative age and performance ($p > 0.05$).

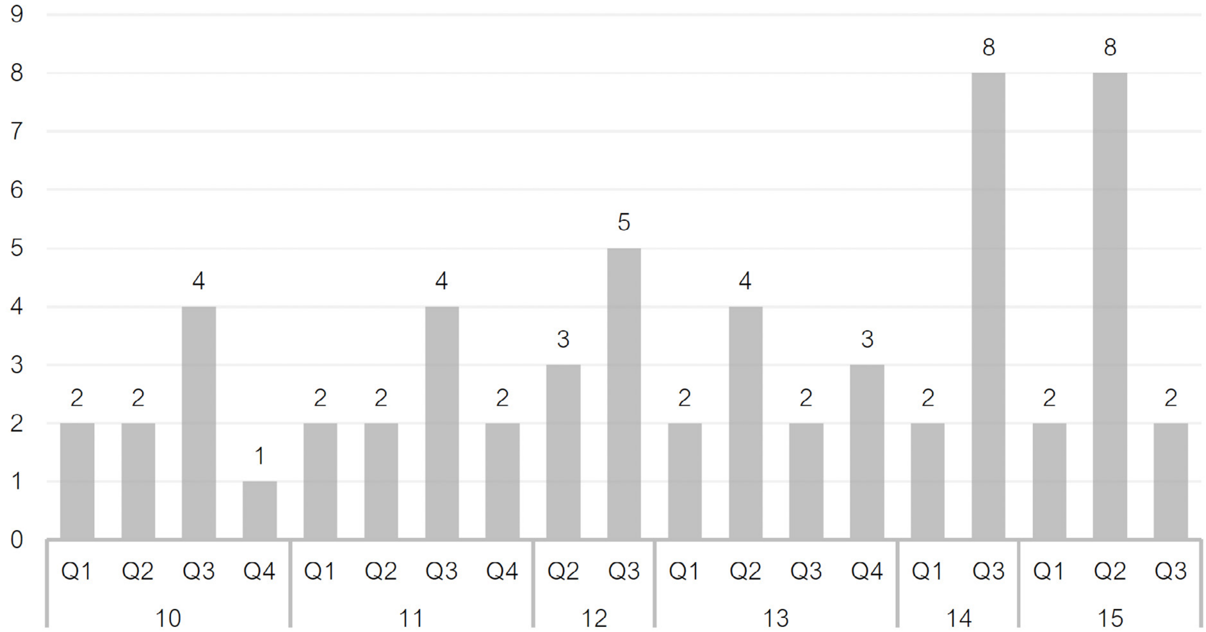

Figure 1. Frequency count of birth quartile (BQ)

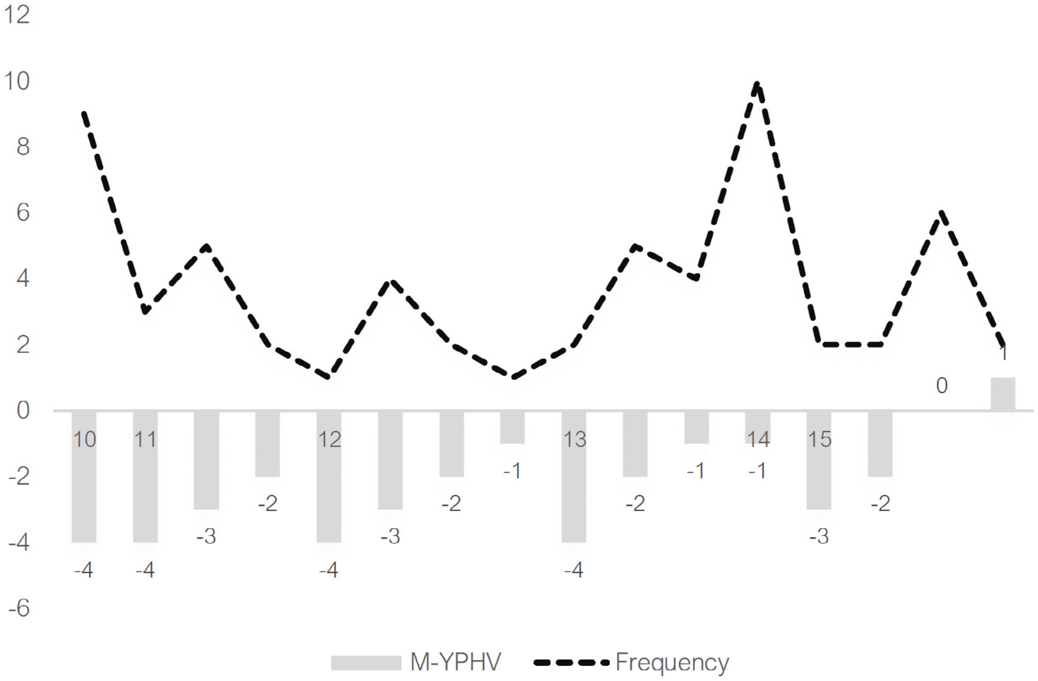

Figure 2. Frequency count of maturity

Table 1. Descriptive statistics for anthropometric and physical performance.

V	Age	W (kg)	H (cm)	SH (cm)	S & R (cm)	LS (kg)	CMJ (cm)	S (s)	SB (s)	20-m (s)	20-m B (s)	WS	MS	JS	MQ
10 years (n=9)															
Min	10.16	28.1	135.9	60	16	35	23	6.47	8.81	4	3.71	42	18	50	115
Max	10.86	43.8	147.6	64.7	23.5	67.5	34	7.62	10.85	4.3	6.7	72	21	66	157
M ± SD	10.6 ± 0.2	35.3 ± 6	142.9 ± 4.1	62.8 ± 1.9	20.2 ± 2	51.5 ± 12.7	29.1 ± 4	7.1 ± 0.4	9.6 ± 0.8	4.1 ± 0.1	4.5 ± 0.8	56.3 ± 12.4	20.1 ± 0.9	57.7 ± 6.4	134.2 ± 17.8
11 years (n=10)															
Min	11.25	33	142	63.1	14	38.5	28	6.57	8.15	3.87	3.99	38	20	45	118
Max	11.92	81.3	160	73.5	29.5	105.5	38	7.16	11.22	4.73	5.31	72	28	70	155
M ± SD	11.5 ± 0.1	45.1 ± 15.2	149 ± 6.8	66.5 ± 3.5	23.4 ± 5.5	72.2 ± 17.6	32.6 ± 3.3	6.8 ± 0.1	9.2 ± 0.8	4.1 ± 0.2	4.5 ± 0.4	53.8 ± 10.8	22.2 ± 2.2	57.8 ± 7.8	133.8 ± 11.4
12 years (n=8)															
Min	12.29	33.2	146.3	63.2	13.5	32	26	6.28	8	3.69	3.68	24	13	53	102
Max	12.89	61.8	163	74.3	29	83	43	7.79	11.67	6.28	4.85	71	33	83	170
M ± SD	12.6 ± 0.2	46.1 ± 10	154.4 ± 5.8	68 ± 3.7	22 ± 5.5	63.3 ± 15	32.3 ± 5	6.8 ± 0.4	9.3 ± 1.4	4.4 ± 0.8	4.2 ± 0.3	47.5 ± 14.4	24.3 ± 6.3	67.1 ± 13.2	139 ± 27.4
13 years (n=11)															
Min	13.31	34.3	146.5	56.8	20	48	30	6.27	7.78	3.55	3.94	35	18	38	99
Max	13.74	71.5	176.2	80.5	36.5	104	42	7.22	10.53	4.4	4.75	72	29	90	191
M ± SD	13.5 ± 0.1	50.1 ± 15.4	157.8 ± 11.7	69.4 ± 7.5	25.3 ± 6	71 ± 19.8	35.5 ± 5.6	6.8 ± 04	9.1 ± 1	4 ± 0.2	4.4 ± 0.3	59 ± 16.2	23 ± 3.6	61.8 ± 17.9	143.9 ± 34
14 years (n=10)															
Min	14.14	50.8	160.4	73.4	15.5	60	27	6.34	8.1	3.4	3.72	30	20	53	133
Max	14.39	62.9	175	76.8	26.5	116.5	46	7.48	10.28	4.52	5	60	36	89	176
M ± SD	14.3 ± 0	57.2 ± 4.1	167.9 ± 5.5	74.7 ± 1.3	21.5 ± 3.8	98.9 ± 22.1	36 ± 6.4	6.6 ± 0.4	8.9 ± 0.7	3.8 ± 0.4	4.2 ± 0.4	45.8 ± 12.5	28.2 ± 5.9	75.4 ± 14.2	149.4 ± 15.9
15 years (n=12)															
Min	15.01	33.8	144.4	63.6	21	64.5	35	6.22	7.93	3.39	3.62	17	22	66	114
Max	15.78	91.9	185	83.5	34	134	44	7.29	10	4.35	4.94	64	33	97	176
M ± SD	15.4 ± 0.2	56.7 ± 20.3	167.2 ± 14.5	75 ± 7.9	27.6 ± 5.6	95.8 ± 25	40 ± 3.5	6.7 ± 0.3	8.5 ± 0.7	3.7 ± 0.3	4.1 ± 0.4	47.8 ± 16	27.6 ± 3.4	82 ± 11.3	157.5 ± 21
Overall (N=60)															
Min	10.16	28.1	135.9	56.8	13.5	32	23	6.22	7.78	3.39	3.62	17	13	38	99
Max	15.78	91.9	185	83.5	36.5	134	46	7.79	11.67	6.28	6.7	72	36	97	191
M ± SD	13.1 ± 1.6	49 ± 15.1	157.2 ± 12.8	69.7 ± 6.7	23.6 ± 5.4	76.9 ± 25.3	34.6 ± 5.7	6.8 ± 0.4	9.1 ± 0.9	4 ± 0.4	4.3 ± 0.5	51.7 ± 14.3	24.4 ± 4.9	67.5 ± 15.3	143.7 ± 23.4

Note: V: Variables; W: Weight; H: Height; S&R: Sit and Reach; LS: Leg Strenght; CMJ: Counter Movement Jump; S: Slalom; SB: Slalom with a ball; 20-m B: 20-m sprint with a ball; WS: Walking back side; MS: Moving Sideways; JS: Jumping sideways; MQ: motor coefficients.

Table 2. A post hoc comparison was conducted among the groups exhibiting statistically significant differences in the ANCOVA analysis for physical performance variables.

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Sit and reach (cm)	10	11	-3.0056	2.36666	1.000	-10.2745	4.2634
		12	-2.9806	2.50288	1.000	-10.6679	4.7068
		13	-4.5146	2.31515	0.846	-11.6254	2.5961
		14	-1.1056	2.36666	1.000	-8.3745	6.1634
		15	-7.2722*	2.27132	0.034	-14.2484	-0.2961
	11	10	3.0056	2.36666	1.000	-4.2634	10.2745
		12	0.0250	2.44328	1.000	-7.4793	7.5293
		13	-1.5091	2.25058	1.000	-8.4215	5.4033
		14	1.9000	2.30354	1.000	-5.1751	8.9751
		15	-4.2667	2.20547	0.874	-11.0406	2.5072
	12	10	2.9806	2.50288	1.000	-4.7068	10.6679
		11	-0.0250	2.44328	1.000	-7.5293	7.4793
		13	-1.5341	2.39341	1.000	-8.8852	5.8170
		14	1.8750	2.44328	1.000	-5.6293	9.3793
		15	-4.2917	2.35104	1.000	-11.5127	2.9293
	13	10	4.5146	2.31515	0.846	-2.5961	11.6254
		11	1.5091	2.25058	1.000	-5.4033	8.4215
		12	1.5341	2.39341	1.000	-5.8170	8.8852
		14	3.4091	2.25058	1.000	-3.5033	10.3215
		15	-2.7576	2.15010	1.000	-9.3614	3.8462
	14	10	1.1056	2.36666	1.000	-6.1634	8.3745
		11	-1.9000	2.30354	1.000	-8.9751	5.1751
		12	-1.8750	2.44328	1.000	-9.3793	5.6293
		13	-3.4091	2.25058	1.000	-10.3215	3.5033
		15	-6.1667	2.20547	0.107	-12.9406	0.6072
	15	10	7.2722*	2.27132	0.034	0.2961	14.2484
		11	4.2667	2.20547	0.874	-2.5072	11.0406
		12	4.2917	2.35104	1.000	-2.9293	11.5127
		13	2.7576	2.15010	1.000	-3.8462	9.3614
		14	6.1667	2.20547	0.107	-0.6072	12.9406
Leg strength (kg)	10	11	-25.139	9.0405	0.112	-52.906	2.628
		12	-9.389	9.5609	1.000	-38.754	19.976
		13	-25.298	8.8437	0.090	-52.461	1.865
		14	-51.789*	9.0405	0.000	-79.556	-24.022
		15	-48.722*	8.6763	0.000	-75.371	-22.074
	11	10	25.139	9.0405	0.112	-2.628	52.906
		12	15.750	9.3332	1.000	-12.916	44.416
		13	-0.159	8.5971	1.000	-26.564	26.246
		14	-26.650	8.7994	0.056	-53.677	0.377
		15	-23.583	8.4248	0.106	-49.459	2.293

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Leg strength (kg)	12	10	9.389	9.5609	1.000	-19.976	38.754
		11	-15.750	9.3332	1.000	-44.416	12.916
		13	-15.909	9.1427	1.000	-43.990	12.172
		14	-42.400*	9.3332	0.000	-71.066	-13.734
		15	-39.333*	8.9809	0.001	-66.917	-11.750
	13	10	25.298	8.8437	0.090	-1.865	52.461
		11	0.159	8.5971	1.000	-26.246	26.564
		12	15.909	9.1427	1.000	-12.172	43.990
		14	-26.491*	8.5971	0.049	-52.896	-0.086
		15	-23.424	8.2133	0.092	-48.650	1.802
	14	10	51.789*	9.0405	0.000	24.022	79.556
		11	26.650	8.7994	0.056	-0.377	53.677
		12	42.400*	9.3332	0.000	13.734	71.066
		13	26.491*	8.5971	0.049	0.086	52.896
		15	3.067	8.4248	1.000	-22.809	28.943
	15	10	48.722*	8.6763	0.000	22.074	75.371
		11	23.583	8.4248	0.106	-2.293	49.459
		12	39.333*	8.9809	0.001	11.750	66.917
		13	23.424	8.2133	0.092	-1.802	48.650
		14	-3.067	8.4248	1.000	-28.943	22.809
CMJ Without arm (cm)	10	11	-4.71	2.129	0.468	-11.25	1.83
		12	-3.49	2.252	1.000	-10.40	3.43
		13	-6.66*	2.083	0.035	-13.05	-0.26
		14	-8.11*	2.129	0.005	-14.65	-1.57
		15	-12.11*	2.044	0.000	-18.39	-5.83
	11	10	4.71	2.129	0.468	-1.83	11.25
		12	1.23	2.198	1.000	-5.53	7.98
		13	-1.95	2.025	1.000	-8.17	4.27
		14	-3.40	2.073	1.000	-9.77	2.97
		15	-7.40*	1.984	0.007	-13.49	-1.31
	12	10	3.49	2.252	1.000	-3.43	10.40
		11	-1.23	2.198	1.000	-7.98	5.53
		13	-3.17	2.154	1.000	-9.78	3.44
		14	-4.63	2.198	0.601	-11.38	2.13
		15	-8.63*	2.115	0.002	-15.12	-2.13
	13	10	6.66*	2.083	0.035	0.26	13.05
		11	1.95	2.025	1.000	-4.27	8.17
		12	3.17	2.154	1.000	-3.44	9.78
		14	-1.45	2.025	1.000	-7.67	4.77
		15	-5.45	1.935	0.101	-11.40	0.49

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
CMJ Without arm (cm)	14	10	8.11*	2.129	0.005	1.57	14.65
		11	3.40	2.073	1.000	-2.97	9.77
		12	4.63	2.198	0.601	-2.13	11.38
		13	1.45	2.025	1.000	-4.77	7.67
		15	-4.00	1.984	0.732	-10.09	2.09
	15	10	12.11*	2.044	0.000	5.83	18.39
		11	7.40*	1.984	0.007	1.31	13.49
		12	8.63*	2.115	0.002	2.13	15.12
		13	5.45	1.935	0.101	-0.49	11.40
		14	4.00	1.984	0.732	-2.09	10.09
Slalom (s)	10	11	0.1414	0.18008	1.000	-0.4117	0.6946
		12	-0.0156	0.19045	1.000	-0.6005	0.5694
		13	0.2226	0.17616	1.000	-0.3184	0.7637
		14	0.3004	0.18008	1.000	-0.2527	0.8536
		15	0.2611	0.17283	1.000	-0.2697	0.7919
	11	10	-0.1414	0.18008	1.000	-0.6946	0.4117
		12	-0.1570	0.18591	1.000	-0.7280	0.4140
		13	0.0812	0.17125	1.000	-0.4448	0.6072
		14	0.1590	0.17528	1.000	-0.3794	0.6974
		15	0.1197	0.16782	1.000	-0.3958	0.6351
	12	10	0.0156	0.19045	1.000	-0.5694	0.6005
		11	0.1570	0.18591	1.000	-0.4140	0.7280
		13	0.2382	0.18212	1.000	-0.3212	0.7975
		14	0.3160	0.18591	1.000	-0.2550	0.8870
		15	0.2767	0.17890	1.000	-0.2728	0.8261
	13	10	-0.2226	0.17616	1.000	-0.7637	0.3184
		11	-0.0812	0.17125	1.000	-0.6072	0.4448
		12	-0.2382	0.18212	1.000	-0.7975	0.3212
		14	0.0778	0.17125	1.000	-0.4482	0.6038
		15	0.0385	0.16360	1.000	-0.4640	0.5410
	14	10	-0.3004	0.18008	1.000	-0.8536	0.2527
		11	-0.1590	0.17528	1.000	-0.6974	0.3794
		12	-0.3160	0.18591	1.000	-0.8870	0.2550
		13	-0.0778	0.17125	1.000	-0.6038	0.4482
		15	-0.0393	0.16782	1.000	-0.5548	0.4761
	15	10	-0.2611	0.17283	1.000	-0.7919	0.2697
		11	-0.1197	0.16782	1.000	-0.6351	0.3958
		12	-0.2767	0.17890	1.000	-0.8261	0.2728
		13	-0.0385	0.16360	1.000	-0.5410	0.4640
		14	0.0393	0.16782	1.000	-0.4761	0.5548
Slalom B (s)	10	11	0.7174	0.43858	1.000	-0.6296	2.0645
		12	0.0594	0.46382	1.000	-1.3651	1.4840
		13	0.6399	0.42903	1.000	-0.6778	1.9576
		14	1.0524	0.43858	0.298	-0.2946	2.3995
		15	1.4444*	0.42091	0.017	0.1517	2.7372

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Slalom B (s)	11	10	-0.7174	0.43858	1.000	-2.0645	0.6296
		12	-0.6580	0.45277	1.000	-2.0486	0.7326
		13	-0.0775	0.41706	1.000	-1.3585	1.2034
		14	0.3350	0.42688	1.000	-0.9761	1.6461
		15	0.7270	0.40870	1.000	-0.5283	1.9823
	12	10	-0.0594	0.46382	1.000	-1.4840	1.3651
		11	0.6580	0.45277	1.000	-0.7326	2.0486
		13	0.5805	0.44353	1.000	-0.7818	1.9427
		14	0.9930	0.45277	0.489	-0.3976	2.3836
		15	1.3850*	0.43568	0.037	0.0469	2.7231
	13	10	-0.6399	0.42903	1.000	-1.9576	0.6778
		11	0.0775	0.41706	1.000	-1.2034	1.3585
		12	-0.5805	0.44353	1.000	-1.9427	0.7818
		14	0.4125	0.41706	1.000	-0.8684	1.6935
		15	0.8045	0.39844	0.727	-0.4192	2.0283
	14	10	-1.0524	0.43858	0.298	-2.3995	0.2946
		11	-0.3350	0.42688	1.000	-1.6461	0.9761
		12	-0.9930	0.45277	0.489	-2.3836	0.3976
		13	-0.4125	0.41706	1.000	-1.6935	0.8684
		15	0.3920	0.40870	1.000	-0.8633	1.6473
	15	10	-1.4444*	0.42091	0.017	-2.7372	-0.1517
		11	-0.7270	0.40870	1.000	-1.9823	0.5283
		12	-1.3850*	0.43568	0.037	-2.7231	-0.0469
		13	-0.8045	0.39844	0.727	-2.0283	0.4192
		14	-0.3920	0.40870	1.000	-1.6473	0.8633
20-m Sprint (s)	10	11	-0.0263	0.21279	1.000	-0.6799	0.6272
		12	-0.6546	0.22504	0.079	-1.3458	0.0366
		13	0.0903	0.20816	1.000	-0.5490	0.7296
		14	0.3467	0.21279	1.000	-0.3069	1.0002
		15	0.4183	0.20422	0.681	-0.2089	1.0456
	11	10	0.0263	0.21279	1.000	-0.6272	0.6799
		12	-0.6283	0.21968	0.090	-1.3030	0.0465
		13	0.1166	0.20236	1.000	-0.5049	0.7382
		14	0.3730	0.20712	1.000	-0.2631	1.0091
		15	0.4447	0.19830	0.436	-0.1644	1.0537
	12	10	0.6546	0.22504	0.079	-0.0366	1.3458
		11	0.6283	0.21968	0.090	-0.0465	1.3030
		13	.7449*	0.21520	0.016	0.0839	1.4058
		14	1.0012*	0.21968	0.000	0.3265	1.6760
		15	1.0729*	0.21139	0.000	0.4237	1.7222
	13	10	-0.0903	0.20816	1.000	-0.7296	0.5490
		11	-0.1166	0.20236	1.000	-0.7382	0.5049
		12	-.7449*	0.21520	0.016	-1.4058	-0.0839
		14	0.2564	0.20236	1.000	-0.3652	0.8779
		15	0.3280	0.19332	1.000	-0.2657	0.9218

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
20-m Sprint (s)	14	10	-0.3467	0.21279	1.000	-1.0002	0.3069
		11	-0.3730	0.20712	1.000	-1.0091	0.2631
		12	-1.0012*	0.21968	0.000	-1.6760	-0.3265
		13	-0.2564	0.20236	1.000	-0.8779	0.3652
		15	0.0717	0.19830	1.000	-0.5374	0.6807
	15	10	-0.4183	0.20422	0.681	-1.0456	0.2089
		11	-0.4447	0.19830	0.436	-1.0537	0.1644
		12	-1.0729*	0.21139	0.000	-1.7222	-0.4237
		13	-0.3280	0.19332	1.000	-0.9218	0.2657
		14	-0.0717	0.19830	1.000	-0.6807	0.5374
20-m Sprint B (s)	10	11	0.2562	0.25997	1.000	-0.5423	1.0547
		12	0.4210	0.27493	1.000	-0.4235	1.2654
		13	0.4386	0.25431	1.000	-0.3425	1.2197
		14	0.5902	0.25997	0.408	-0.2083	1.3887
		15	0.6872	0.24950	0.120	-0.0791	1.4535
	11	10	-0.2562	0.25997	1.000	-1.0547	0.5423
		12	0.1648	0.26839	1.000	-0.6596	0.9891
		13	0.1824	0.24722	1.000	-0.5769	0.9417
		14	0.3340	0.25304	1.000	-0.4432	1.1112
		15	0.4310	0.24226	1.000	-0.3131	1.1751
	12	10	-0.4210	0.27493	1.000	-1.2654	0.4235
		11	-0.1648	0.26839	1.000	-0.9891	0.6596
		13	0.0176	0.26291	1.000	-0.7899	0.8251
		14	0.1693	0.26839	1.000	-0.6551	0.9936
		15	0.2662	0.25825	1.000	-0.5270	1.0595
	13	10	-0.4386	0.25431	1.000	-1.2197	0.3425
		11	-0.1824	0.24722	1.000	-0.9417	0.5769
		12	-0.0176	0.26291	1.000	-0.8251	0.7899
		14	0.1516	0.24722	1.000	-0.6077	0.9109
		15	0.2486	0.23618	1.000	-0.4768	0.9740
	14	10	-0.5902	0.25997	0.408	-1.3887	0.2083
		11	-0.3340	0.25304	1.000	-1.1112	0.4432
		12	-0.1693	0.26839	1.000	-0.9936	0.6551
		13	-0.1516	0.24722	1.000	-0.9109	0.6077
		15	0.0970	0.24226	1.000	-0.6471	0.8411
	15	10	-0.6872	0.24950	0.120	-1.4535	0.0791
		11	-0.4310	0.24226	1.000	-1.1751	0.3131
		12	-0.2662	0.25825	1.000	-1.0595	0.5270
		13	-0.2486	0.23618	1.000	-0.9740	0.4768
		14	-0.0970	0.24226	1.000	-0.8411	0.6471
MQ	10	11	4.31	10.323	1.000	-27.39	36.02
		12	8.11	10.917	1.000	-25.42	41.64
		13	0.20	10.098	1.000	-30.81	31.22
		14	-11.29	10.323	1.000	-42.99	20.42
		15	-19.39	9.907	0.833	-49.82	11.04

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
MQ	11	10	-4.31	10.323	1.000	-36.02	27.39
		12	3.80	10.657	1.000	-28.93	36.53
		13	-4.11	9.816	1.000	-34.26	26.04
		14	-15.60	10.047	1.000	-46.46	15.26
		15	-23.70	9.620	0.255	-53.25	5.85
	12	10	-8.11	10.917	1.000	-41.64	25.42
		11	-3.80	10.657	1.000	-36.53	28.93
		13	-7.91	10.439	1.000	-39.97	24.15
		14	-19.40	10.657	1.000	-52.13	13.33
		15	-27.50	10.255	0.145	-59.00	4.00
	13	10	-0.20	10.098	1.000	-31.22	30.81
		11	4.11	9.816	1.000	-26.04	34.26
		12	7.91	10.439	1.000	-24.15	39.97
		14	-11.49	9.816	1.000	-41.64	18.66
		15	-19.59	9.378	0.622	-48.39	9.21
	14	10	11.29	10.323	1.000	-20.42	42.99
		11	15.60	10.047	1.000	-15.26	46.46
		12	19.40	10.657	1.000	-13.33	52.13
		13	11.49	9.816	1.000	-18.66	41.64
		15	-8.10	9.620	1.000	-37.65	21.45
	15	10	19.39	9.907	0.833	-11.04	49.82
		11	23.70	9.620	0.255	-5.85	53.25
		12	27.50	10.255	0.145	-4.00	59.00
		13	19.59	9.378	0.622	-9.21	48.39
		14	8.10	9.620	1.000	-21.45	37.65

Table 3. Descriptive statistics for all measured variables across birth quartiles (adjusted mean ± SD).

Variables	Q1 (n=10)	Q2 (n=22)	Q3 (n=22)	Q4 (n=6)
S & R (cm)	22.6 ± 6.4	22.8 ± 4.5	25 ± 6.3	24.1 ± 2.6
LS (kg)	76.9 ± 23.7	65.4 ± 29.7	87.7 ± 21.7	65.7 ± 19.5
CMJ (cm)	32.3 ± 5.5	32.8 ± 6.5	35.6 ± 5.5	36.3 ± 3.7
S (s)	6.4 ± 0.2	6.9 ± 0.3	6.8 ± 0.4	6.9 ± 0.3
SB (s)	9.5 ± 1	9.5 ± 1.1	8.9 ± 1	8.8 ± 0.4
20-m (s)	4.2 ± 0.4	4.2 ± 0.7	3.8 ± 0.4	4 ± 0.1
20-m B (s)	4.4 ±0.4	4.5 ± 0.7	4.1 ± 0.2	4.6 ± 0.3
WS	53.9 ± 10.1	49.9 ± 17.1	50.1 ± 13.1	57.8 ± 13.2
MS	20.9 ± 3	23.3 ± 3.7	27.3 ± 5.7	21.6 ± 1
JS	59.6 ± 21.2	64.7 ± 10.4	71.9 ± 17.2	63 ± 8.1
MQ	134.4 ± 27.8	137.9 ± 21.5	149.4 ± 23.9	142.5 ± 19.6

Note: W: Weight; H: Height; S&R: Sit and Reach; LS: Leg Strenght; CMJ: Counter Movement Jump; S: Slalom; SB: Slalom with a ball; 20-m B: 20-m sprint with a ball; WS: Walking back side; MS: Moving Sideways; JS: Jumping sideways; MQ: motor coefficients.

Table 4. Descriptive statistics for all measured variables across maturity classifications (adjusted mean ± SD).

V	Age	W (kg)	H (cm)	SH (cm)	S & R (cm)	LS (kg)	CMJ (cm)	S (s)	SB (s)	20-m (s)	20-m B (s)	WS	MS	JS	MQ
-4 (n=16)															
Min	10.16	28.1	135.9	56.8	16	32	23	6.47	8.81	3.94	3.71	37	18	45	115
Max	13.31	43.8	147.6	64.7	28	81	38	7.62	11.33	6.28	6.7	72	28	66	157
M ± SD	11.3 ± 1	33.3 ± 4.5	142.8 ± 4.2	61.7 ± 2.5	22.2 ± 3.4	50 ± 15.4	30.3 ± 4.7	7.0056	10 ± 0.8	4.4 ± 0.7	4.7 ± 0.8	56.6 ± 13	20.7 ± 2.2	57.9 ± 6	135.3 ± 13.5
-3 (n=11)															
Min	11.39	33	143	63.6	16.5	38.5	26	6.5	8.25	3.55	3.85	39	20	52	122
Max	15.18	57.2	156	68.5	29.5	80.5	36	7	11.22	4.91	5.31	71	31	79	170
M ± SD	12.5 ± 1.3	41.7 ± 8	150 ± 4.6	66 ± 1.9	24.5 ± 4.5	64.6 ± 11.9	32.2 ± 3.3	6.8 ± 0.1	9.2 ± 0.8	4.1 ± 0.5	4.3 ± 0.4	56.3 ± 9.9	25 ± 3.8	64.3 ± 10.7	145.8 ± 18.7
-2 (n=10)															
Min	11.51	33.8	144.4	66	14	57.5	29	6.27	8.15	3.94	4	24	18	38	99
Max	15.78	81.3	163.1	73.5	29	105.5	41	7.79	10.53	4.46	5.22	72	29	70	165
M ± SD	13.5 ± 1.4	49.6 ± 15.6	155.2 ± 8.5	69.9 ± 2.5	21.7 ± 4	72.8 ± 13.1	33.5 ± 4.5	6.8 ± 0.5	9.2 ± 0.9	4.2 ± 0.2	4.4 ± 0.3	52 ± 15.4	22.5 ± 4	54.7 ± 13.4	129.2 ± 29.7
-1 (n=15)															
Min	12.89	50.8	160	70.9	13.5	60	27	6.34	7.78	3.4	3.72	30	13	53	114
Max	14.39	71.5	176.2	80.5	36.5	116.5	46	7.48	11.67	4.52	5	72	36	90	191
M ± SD	14 ± 0.4	59.5 ± 6.1	167.7 ± 6.2	74.9 ± 2.8	22.7 ± 6.6	94.5 ± 21.2	35.6 ± 6.3	6.7 ± 0.4	9 ± 1.1	3.8 ± 0.3	4.2 ± 0.4	47.8 ± 14.5	26.7 ± 6.3	73.2 ± 15.6	147.8 ± 26
0 (n=6)															
Min	15.38	53.1	171	76.6	21	93	40	6.22	7.93	3.39	3.62	46	26	84	163
Max	15.74	69.7	185	82	34	117	44	7.29	8.28	3.59	3.95	50	33	97	176
M ± SD	15.5 ± 0.1	58.7 ± 8.5	175.6 ± 7.2	79 ± 2.4	29.1 ± 6.3	101.3 ± 12.1	42 ± 1.7	6.6 ± 0.5	8 ± 0.1	3.5 ± 0	3.8 ± 0.1	48 ± 1.7	29.3 ± 3.1	91.6 ± 6	169 ± 5.8
1 (n=2)															
Min	15.01	91.9	178.3	83.5	32.5	134	43	6.74	8.04	4.07	4.94	17	22	75	114
Max	15.04	91.3	178.7	83.5	32.5	136	44	7	8	5	6	18	24	77	116
M ± SD	15 ± 2	91.9 ± 3	178.3 ± 1	83.5 ± 4	32.5 ± 6.1	134 ± 3.2	43 ± 2	6.74 ± 3	8.04 ± 4	4 ± 2	4.9 ± 0	17 ± 0	22 ± 2	75 ± 3	114 ± 1

Note: V: Variables; W: Weight; H: Height; S&R: Sit and Reach; LS: Leg Strength; CMJ: Counter Movement Jump; S: Slalom; SB: Slalom with a ball; 20-m B: 20-m sprint with a ball; WS: Walking back side; MS: Moving Sideways; JS: Jumping sideways; MQ: motor coefficients.

Table 5. Pearson correlations between relative age and biological age for each age group

V	Correlations	RAE	M-YPHV	S & R (cm)	LS (kg)	CMJ (cm)	S (s)	SB (s)	20-m (s)	20-m B (s)	WS	MS	JS	MQ
RAE	Pearson Correlation		-0.078	0.155	0.105	0.242	0.245	-0.245	-0.172	-0.108	0.017	.258*	0.17	0.177
	Sig. (2-tailed)		0.555	0.236	0.426	0.063	0.059	0.059	0.189	0.413	0.9	0.047	0.193	0.177
M-YPHV	Pearson Correlation	-0.078		.291*	.807**	.601**	-.299*	-.529**	-.462**	-.287*	-.418**	.428**	.552**	0.2
	Sig. (2-tailed)	0.555		0.024	0.001	0.001	0.02	0.001	0.001	0.026	0.001	0.001	0.001	0.125
S & R (cm)	Pearson Correlation	0.155	.291*		.425**	.545**	0.028	-.518**	-0.206	-0.176	-0.023	.451**	.498**	.409**
	Sig. (2-tailed)	0.236	0.024		0.001	0.001	0.829	0.001	0.115	0.178	0.863	0.001	0.001	0.001
LS (kg)	Pearson Correlation	0.105	.807**	.425**		.696**	-.315*	-.528**	-.543**	-.359**	-.435**	.518**	.569**	0.221
	Sig. (2-tailed)	0.426	0.001	0.001		0.001	0.014	0.001	0.001	0.005	0.001	0.001	0.001	0.09
CMJ (cm)	Pearson Correlation	0.242	.601**	.545**	.696**		-.316*	-.545**	-.464**	-.415**	-0.221	.530**	.712**	.447**
	Sig. (2-tailed)	0.063	0.001	0.001	0.001		0.014	0.001	0.001	0.001	0.09	0.001	0.001	0.001
S (s)	Pearson Correlation	0.245	-.299*	0.028	-.315*	-.316*		0.153	0.217	0.105	-0.004	-0.017	-0.113	-0.08
	Sig. (2-tailed)	0.059	0.02	0.829	0.014	0.014		0.242	0.096	0.424	0.975	0.895	0.39	0.541
SB (s)	Pearson Correlation	-0.245	-.529**	-.518**	-.528**	-.545**	0.153		.493**	.431**	-0.055	-.567**	-.525**	-.498**
	Sig. (2-tailed)	0.059	0.001	0.001	0.001	0.001	0.242		0.001	0.001	0.674	0.001	0.001	0.001
20-m (s)	Pearson Correlation	-0.172	-.462**	-0.206	-.543**	-.464**	0.217	.493**		.416**	-0.162	-.415**	-.601**	-.581**
	Sig. (2-tailed)	0.189	0.001	0.115	0.001	0.001	0.096	0.001		0.001	0.216	0.001	0.001	0.001
20-m B (s)	Pearson Correlation	-0.108	-.287*	-0.176	-.359**	-.415**	0.105	.431**	.416**		0.127	-.445**	-.393**	-.275*
	Sig. (2-tailed)	0.413	0.026	0.178	0.005	0.001	0.424	0.001	0.001		0.333	0.001	0.002	0.033
WS	Pearson Correlation	0.017	-.418**	-0.023	-.435**	-0.221	-0.004	-0.055	-0.162	0.127		0.021	-0.02	.597**
	Sig. (2-tailed)	0.9	0.001	0.863	0.001	0.09	0.975	0.674	0.216	0.333		0.874	0.882	0.001
MS	Pearson Correlation	.258*	.428**	.451**	.518**	.530**	-0.017	-.567**	-.415**	-.445**	0.021		.601**	.619**
	Sig. (2-tailed)	0.047	0.001	0.001	0.001	0.001	0.895	0.001	0.001	0.001	0.874		0.001	0.001
JS	Pearson Correlation	0.17	.552**	.498**	.569**	.712**	-0.113	-.525**	-.601**	-.393**	-0.02	.601**		.773**
	Sig. (2-tailed)	0.193	0.001	0.001	0.001	0.001	0.39	0.001	0.001	0.002	0.882	0.001		0.001
MQ	Pearson Correlation	0.177	0.2	.409**	0.221	.447**	-0.08	-.498**	-.581**	-.275*	.597**	.619**	.773**	
	Sig. (2-tailed)	0.177	0.125	0.001	0.09	0.001	0.541	0.001	0.001	0.033	0.001	0.001	0.001	

Note: V: Variables; W: Weight; H: Height; S&R: Sit and Reach; LS: Leg Strenght; CMJ: Counter Movement Jump; S: Slalom; SB: Slalom with a ball; 20-m B: 20-m sprint with a ball; WS: Walking back side; MS: Moving Sideways; JS: Jumping sideways; MQ: motor coefficients.

DISCUSSION

The current study highlights the correlation between juvenile soccer athletes' maturation status and performance proficiencies. In particular, a higher level of maturation is associated with improved performance in a significant portion of age groups. This connection becomes particularly significant in the context of advanced maturation and relatively older age. These findings substantiate the predominant proposition that heightened maturation, distinguished from proximity in relative age, is positively correlated with superior performance outcomes among males within the Turkish academy soccer framework.

Soccer is the most globally pervasive sport, including Turkey (29). While most juveniles in Turkey do not participate in soccer, a competitive milieu prevails for securing positions in specific teams (2, 30), with several teams identifying the most proficient players in the region, commencing as early as ages 9–10 (31). We found that senior male participants exhibited heightened stature and greater lower limb length, constituting discernible physical attributes. Furthermore, our study examined the prevalence of the Relative Age Effect (RAE) within a cohort of developing soccer participants, along with anthropometric traits, physical aptitude, and parameters relevant to maturation.

Existing suppositions suggest that RAE emanates from augmented physical maturation, resulting in amplified bodily dimensions and a corresponding advantage in performance displayed by elder players (12). RAE has been extensively documented, albeit with its fundamental causative factors predominantly inhabiting the realm of conjecture (18). The present study, however, negates the presence of RAE, evidenced by the absence of a disproportionate representation of birth dates at the commencement of the calendar year. In congruence with our findings, earlier studies by Malina et al. (2007) and Deprez et al. (2012) yielded similar results, with no statistically substantial disparities in body dimensions observed among soccer players born in the initial three months of the year (32, 33). However, according to Carling et al. (2009), Hirose (2009), and Torres-Unda et al. (2013), players born in the inaugural segment of the calendar year manifested greater stature (5, 34, 35). Notably, a study showed no significant effect of distinct age quartiles on physical performance and motor coordination assessments (36). Players exhibiting advanced maturation status, denoted as post-peak height velocity ('post-PHV'), often manifest transient, maturity-related enhancements in anthropometric proportions and physical fitness attributes (37), including better speed, strength, and aerobic fitness levels attributed to hormonal responses from earlier puberty onset (38, 39). Such hormonal influences can augment physical attributes, including strength and sprint capacity (40).

In the current study, the age groups spanning U10 to U15 showed associations between maturation and strength. Similarly, a significant correlation existed between maturation and countermovement jump (CMJ) performance in the U10 cohort, whereas in the U15 grouping, there was a significant correlation between relative age and CMJ performance. Recent findings have substantiated the heightened influence of maturity status upon strength and CMJ performance in fledgling soccer practitioners. Fjørtoft, Pedersen, Sigmundsson, and Vereijken (2011) advocated for a comprehensive battery of physical assessments encompassing an array of motor competencies and fitness parameters such as endurance, strength, flexibility, agility, and balance, aimed at evaluating the physical capacities of young individuals (41). Accordingly, the battery of tests used in the present study involved a diverse spectrum of motor and functional attributes recognised as indicative of physical well-being and functional aptitude in pediatric cohorts (2, 4). Similar outcomes have been shown by Di Credico et al. (2020), where Italian youth players were categorised into three biological groupings: Pre-PHV, Circa-PHV, and Post-PHV. The reported statistically significant distinctions between Pre-PHV and Circa-PHV and between Circa-PHV and Post-PHV parallel our findings of two anthropometric variables (Weight and height) (42). Furthermore, similar patterns in anthropometric variables were also observed by Figueiredo et al. (2009), showing an increase in body mass and height among Portuguese youth players aged 11 and 12, and 13 and 14, categorised into discrete maturity stages (Late, On Time, and Early). Nonetheless, no connections were established between relative age and performance in sit and reach, slalom, sprint, or motor coordination across any age cohorts examined (9).

The present study has successfully demonstrated that implementing maturity status bio-banding is an efficacious strategy for creating distinct and homogenised player groups, each distinguished by inherent characteristics. Within the 'pre-PHV' and 'circa-PHV' bio-banded groups, stature, sitting height, and body mass were consistently lower than their chronologically aged counterparts. In contrast, individuals designated as ‘post-PHV’ exhibited higher values in these metrics (43). This trend underscores the use of maturity status bio-banding in fostering a more equitable competitive environment by mitigating the variance in physical attributes among players within a specific banded cohort, in contrast to the conventional chronological age-based talent development framework (16, 22, 44). Furthermore, our results agree with Drenowatz et al. (2013), who assessed maturity status based on the percentage of adult stature attained within a German cohort of boys and girls (7.6 ± 0.4 years). Early-maturing children exhibited a less favourable cardiovascular risk profile, diminished physical fitness scores, and more time spent watching television relative to their counterparts, akin to the patterns observed in our study (45). Therefore, advanced maturation emerges as a factor that could compromise performance across a spectrum of physical fitness and motor competence evaluations in Turkish youth (2).

The interplay of maturation status with test performance is influenced by age, gender, task nature, and demands (17). Previous research has linked higher physical fitness levels in early maturing children with sports engagement while adjusting for their augmented size and mass (46). However, fundamental motor coordination has drawn less attention in the context of growth and maturation processes (47). Our findings indicate that bio-banding interventions curtail performance in physical fitness assessments compared to chronological age categorisation, suggesting that bio-banding mitigates early maturing players’ dominance and physical edge, prompting them to devote more effort towards honing their technical and tactical prowess to remain competitive against equally matched adversaries (21, 22). Late-maturing players, conversely, tend to partake more actively in match scenarios, perceiving heightened prospects for showcasing leadership (9). Bolstered by increased self-confidence and a diminished perception of injury risk, late-maturing players assume greater involvement in tackling situations (31). Primarily, the aim of employing maturity status bio-banding is to segregate players into cohorts characterised by harmonised maturity-related anthropometric and physical attributes (48). Of all the performance variables included in the Pearson correlation analysis, the most important variables were leg strength and jump.

In conclusion, the primary objective of the present study was to elucidate the intricate interplay among maturation, relative age, physical performance, and motor coordination. The findings delineate that while leg strength and jump performance significantly correlate with maturation, no such consistent connection exists with relative age. Conversely, a recurrent relation between relative age or maturation and physical performance did not emerge. This study highlights the imperative for practitioners to understand that maturation status represents a discrete construct, as underscored by the notable nexus between maturation and physical performance, divergent from relative age. Accordingly, practitioners are encouraged to monitor growth and maturation diligently, employing regular height and weight assessments to establish projected adult stature and maturity status. This proactive approach can aid in interpreting fluctuations in the physical performance of young male academy soccer participants. Furthermore, the assessment of maturity status should be factored into comparing fitness scores among players. This approach ensures that comparisons do not entail the juxtaposition of early and late maturers within the same age cohort but rather entail the comparison of boys possessing analogous maturity statuses. Such nuanced considerations amplify the validity of fitness score comparisons and enhance the accuracy of the insights garnered by practitioners. Finally, the present study underlines the significance of recognising maturation status as a distinct determinant, offering insights into its association with physical performance, and advocates for meticulous monitoring and contextualisation of maturity-related assessments within the evaluation framework of young male academy soccer players.

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AUTHOR CONTRIBUTIONS

Conceptualization, S.H.S, A.Ç, F.G; Methodology, S.H.S, A.Ç, F.G, S.K; Formal Analysis, S.H.S.; Writing Original Draft Preparation, S.H.S; Writing Reviewing and Editing; S.H.S, J.I.E.

DATA AVAILABILITY

Full access to data on request (Houtan.shahidi@

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CONFLICTS OF INTEREST

The Authors have no conflict of interest to declare

INFORMED CONSENT STATEMENT

The parents of all the participants included in the study provided written informed consent/assent.

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