The Main and Interactive Effects of Biological Maturity and Relative Age on Physical Performance in Elite Youth Soccer Players

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Abstract

The main and interactive effect of biological maturity and relative age upon physical performance in adolescent male soccer players was considered. Consistent with previous research, it was hypothesised that participants of greater maturity or born earlier in the selection year would perform better in terms of physical performance tests. This cross-sectional study consisted of 84 male participants aged between 11.3 – 16.2 years from a professional soccer academy in the English Premier League. Date of birth, height, weight and parental height were collected. Sprint, change of direction, counter-movement jump and reactive strength index was considered for physical performance. Relative age was based on birth quarter for the selection year. Maturity status was based upon percentage of predicted adult height attained. Linear regression models highlighted that maturation was associated with performance on all but one of the physical performance tests, reactive strength index. In contrast, relative age only served as a significant predictor of performance on the countermovement jump. This study showed that physical performance (in the tests studied) seems to be related to the biological maturity status of a player but not their relative age. This finding is important because the paper suggests early maturing players perform better in the majority of physical performance tests, and the commonly held belief that relative age effect influences performance may be overstated.

Keywords: biological maturation; relative age; physical performance; youth athletes; soccer

Introduction

The identification and development of talented soccer players are primary objectives of professional soccer academies (Carling et al., 2009). The aspects that define talent in soccer are multi-faceted, meaning that the process of predicting future potential at early ages is challenging (Vaeyens et al., 2009, Reilly et al., 2000b). Previous research has attempted to identify factors that may predispose an individual towards becoming a successful soccer player such as anthropometric and physical (fitness) characteristics (Reilly et al., 2000a, Gil et al., 2007). Many of these attributes can, however, be confounded by the developmental differences that exist among players.

Biological maturation and relative age are two non-modifiable attributes that have been shown to influence player selection, evaluation, and performance in youth soccer (Meylan et al., 2010, Sierra-Díaz et al., 2017). Biological maturation refers to the progress towards the mature adult state, varying among biological systems, and can be defined in terms of status, tempo and timing (Malina et al., 2015). Whereas 'status' refers to the stage of maturation attained at a specific time-point (e.g. skeletal age or stage of pubic hair development); 'tempo' describes the rate at which maturation advances in a specific system. 'Timing' refers to the age at which specific maturational events, such as puberty occur (Malina et al., 2004). Of relevance, children of the same chronological age can demonstrate marked variation in biological maturation and maturity status with some individuals maturing well in advance or delay of their same age peers (Johnson, 2015, Malina et al., 2004). For example, within an under 9's soccer team, it is entirely possible to observe a child with a skeletal age (an established proxy of maturation) of seven years training and competing with a child who has a skeletal age of twelve years (Johnson, 2015). Individual differences in maturation are principally governed by a combination of heritable i.e. genotypic and environmental factors, such as stress, nutrition and social circumstances, as well as ethnicity (Malina et al., 2004). The individual differences have been shown to directly and indirectly influence player performance and selection in youth soccer (Cumming et al., 2017).

From the onset of puberty, boys who mature in advance of their peers possess a marked advantage in term of size and athleticism (Johnson et al., 2017). As the first individuals within their age group to experience the physical changes associated with puberty, these boys are typically taller, heavier, faster, stronger and more powerful than their later maturing peers

(Figueiredo et al., 2009, Johnson et al., 2017, Malina et al., 2015). Consequently, these players are more likely to succeed in sports and activities that demand or prioritise these attributes. Selection biases towards early maturing boys have been well established in soccer and are especially prevalent in professional soccer academies where there is an emphasis upon identifying and developing the most talented youth (Malina, 2003b). To survive in these programmes, talented yet late maturing players must possess or develop exceptional technical, tactical and / or psychological attributes; a phenomenon known as the 'underdog effect'. This hypothesises that younger and / or later maturing players must display these superior attributes (Fumarco et al., 2017, Malina et al., 2015, Cumming et al., 2018a). While these skills may serve as an advantage in the long-term, research suggests that very few of these individuals are retained within the academy system (Hill et al., 2019, Johnson, 2015).

Relative age refers to a child's chronological age within their age group, and is determined by date of birth and the selection cut-off date. Children competing within a single year age group can vary by almost as much as 12 months in terms of their chronological age (Wattie et al., 2015). This relative age effect (RAE) describes a phenomenon whereby players that are born earlier in their selection year have a greater likelihood of representing and succeeding in their youth programmes. A bias has been reported highlighting the recruitment of individuals that are born earlier in their selection year (Helsen et al., 2005), with findings suggesting that 36 – 50% of soccer players were born within the first three months of their selection year, and only between 4 – 17% born within the last three months of their selection year (Carling et al., 2009, Augste and Lames, 2011, Williams, 2010). The underlying causes of the RAE have often been attributed to physiological growth and maturation (Cobley et al., 2009, Carling et al., 2009). However, RAE are observed well in advance of maturity associated selection biases and are also found in many achievement domains that do not require physical propensity e.g. soccer referees (Delorme et al., 2013), head coaches (Cobley et al., 2008), and academia (Musch and Grondin, 2001b).

It is vital to note that relative age and biological maturation are not synonymous. Relative age and biological maturation are independent constructs that exist and operate independently of one another, and are governed by separate factors (i.e. birth and cut-off dates versus genetics / environment). Within a single year age group there is also much greater scope for variation in biological maturity than relative age. Whereas differences in relative age are limited to 12 months, differences in maturity can vary by up to six years (Johnson, 2015). As a consequence, it is entirely possible to be the eldest and least mature player within one's own age group, or vice-versa. More recently, a study of relative age and maturation noted that Portuguese soccer players aged 11 – 13 years, born later in the year were more likely to be advanced in skeletal maturity for their chronological age and sex than their peers born in the first quarter (Figueiredo et al., 2019). The independent nature of relative age and biological maturity can also be observed in the age at which their associated selection biases emerge and how they change with age. Whereas RAE can be observed from six years of age and remain consistent through late childhood and adolescence, maturity associated selection biases only emerge with the onset of puberty and tend to increase in magnitude with age and competitive level (Malina et al., 2004). As RAE may exist well in advance of puberty, it is unlikely that these biases can be attributed to maturity associated differences in athleticism (i.e. speed, power, strength) which are not evident until approximately 11 – 12 years of age (Malina, 2003a, Sherar et al., 2007). Rather RAE are more likely to result from differences in playing experience, cognitive, emotional, behavioural, motor and social development; all of which are more likely to follow age than maturity.

In light of the previous discussion, the purpose of the current study was to investigate the main and interactive effects of maturation and relative age upon fitness parameters; 5m, 20m, change of direction (COD), counter-movement jump (CMJ) and reactive strength index (RSI) in elite youth soccer players. Specifically, it was predicted that maturation and relative age would be positively associated with physical performance as well as anthropometric measures. Further, it was proposed that the performance advantages might be greatest in players who were both more mature and relatively old for their age groups.

Methods

Participants

The sample included 84 male participants aged between 11.3 – 16.2 years from a professional soccer academy in the English Premier League. Participants normally trained two – three times throughout the week and participated in competition once per week. Data collection occurred within the academy during the 2018 – 2019 season. Parents / legal guardians of the participants were informed of the aim of the study, research procedures, requirements, benefits, and risks. They provided written informed consent and the participants also provided assent. Participants were advised that involvement was voluntary and that they could withdraw from the study at any point. Prior to the study commencing, ethical approval was obtained and granted from the Ethics Committee of the Faculty of Science & Engineering, at Manchester Metropolitan University.

Anthropometry and Procedures

Stature (hereafter, 'height'), sitting height (cm), and weight (kg) were measured every two months throughout the competitive playing season (six measurements). Participants wore T -shirt and shorts, and footwear was removed during measurements. Height and sitting height were measured using a fixed Harpenden stadiometer (Holtain Ltd., UK) to the nearest 0.10 cm. Height was measured as the distance from the standing surface to the vertex of the head. Participants were instructed to stand in the normal erect posture with weight equally distributed between both feet. Sitting height was measured as the distance from a flat sitting surface (0.40 cm high box) to the top of the head. Sitting height was subtracted from height to provide an estimate of leg length. Body mass was measured by means of a weighing scale (Tanita®, type BC-420 SMA, Japan) to the nearest 0.10 kg. The height of the participant's biological parents were collected either by academy staff or self-reported by the parents, the self-reported heights were adjusted for overestimation using sex specific equations (Epstein et al., 1995).

Biological Maturity Status

Final adult height in youths can be predicted using the Khamis-Roche method (Khamis and Roche, 1994). This method uses an individual's chronological age, height and weight, in addition to a calculation of mid-parental height of the biological parents (i.e. mean of the heights of biological parents) to predict final adult height. The median error in predicting adult height in boys using this method is 2.2 cm between 4.0 and 17.5 years of age. With predicted adult height as the reference, percentage of predicted mature adult height attained at the time of observation was calculated (Roche et al., 1983), to provide an indication of biological maturity status (Malina, 2014). This is the same index used to group players by maturation in recent studies of bio-banding (Bradley et al., 2019, Abbott et al., 2019, Cumming et al., 2018a). It can be assumed that for children of the same chronological age, those closer to their predicted adult height may be assumed to be more advanced in maturation compared to those further away from their predicted adult height. For example, a boy that is 90% of his predicted adult height would be considered less mature than a boy of the same chronological age who has achieved 95% of his predicted adult height.

Estimated biological maturity status was expressed as a 'z – score' relative to age and sex specific means and standard deviations for percentage of mature height attained at half-yearly intervals (Bayer and Bayley, 1959). The z – scores were also used to classify each participant as either early, on–time or late in maturity, as used in previous studies (Drenowatz et al., 2013, Cumming et al., 2009, Gillison et al., 2017). Individuals that achieved a z - score of between –1 to +1 were classified as on–time in maturity status, if an individual achieved z – score greater than +1 were defined as early in maturity status, and if an individual achieved a z – score below than –1 they were defined as late in maturity status.

Relative Age

The selection year for youth soccer in England spans 1st September – 31st August. Relative age was established for each participant using their date of birth and the cut-off date of their selection year group (31st August). To allow comparison with previous literature, relative age was classified into birth quartiles. These were defined as quarter one (oldest – Q1): 1st September – 30th November; quarter two (Q2): 1st December –28th (29th) February; quarter three (Q3): 1st March – 31st May; and quarter four (youngest Q4): 1st June – 31st August.

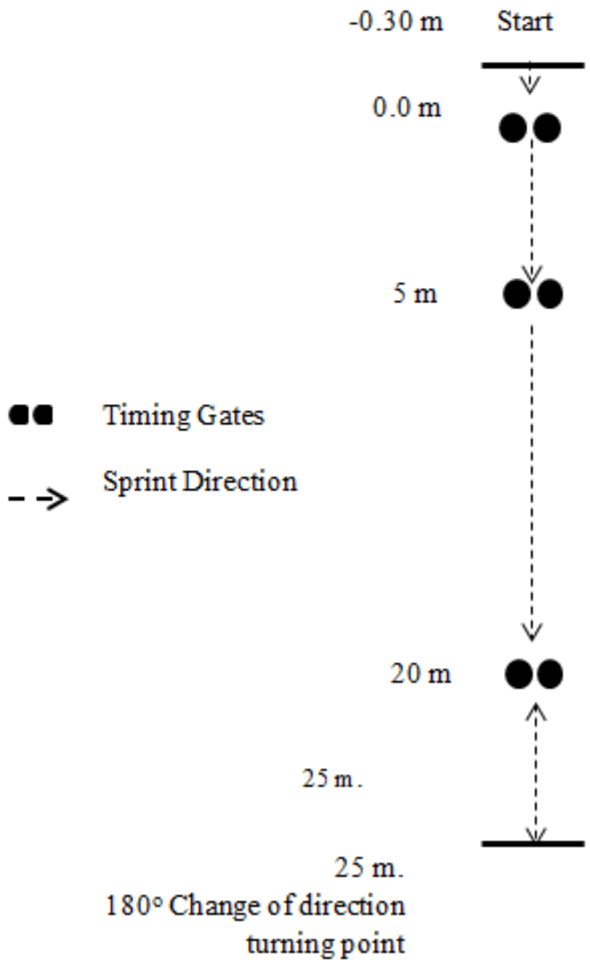
The measure of relative age was also expressed as a decimal, using the difference between a participant's birthdate and the selection cut-off date, divided by the number of days in a year (Cumming et al., 2018b). Relative age was expressed as a value between 0.00 - 0.99, with these values representing the youngest to oldest, respectively.

Physical Performance Tests

Following the collection of anthropometric variables, participants then undertook a dynamic 10 minute warm-up with a qualified youth soccer coach. All participants were tested in their current age groups within the same week at the start of their training session. The sprinting and change of direciton abilities of the participants was evaluated on 4G artificial turf. Participants were instructed to complete all tests in the following order: sprinting (5 m and 20m), change of direction, countermovement jumps and finally, drop jumps. A recovery period of 10 min was given between each test condition to avoid fatigue-induced effects (Trecroci et al., 2018).

Sprint Test

The sprinting abilities of participants were evaluated on 4G artificial turf by 20 m sprint times (standing start), with 5 m and 20 m split times. Gates were positioned at 0 m, 5 m and 20 m, enabling a sprint time to be recorded between 0 m and 5 m, 5 m and 20 m and 0 m and 20 m. Earlier research has highlighted reliability coefficients of variation were <2.7% for youth team-sport players performing all-out sprints over similar distances on similar surfaces (Oliver et al., 2006). All participants performed a familiarisation session to practice the tests and become accustomed with the procedures. For all sprints, participants adopted a two-point stance, with the front foot placed 0.30 m before (– 0.30 m) the initial timing gate (0 m) to prevent early triggering, and were instructed to sprint as fast as possible in a straight line to the turning point, which was placed 5 m beyond the final gate (25 m). Time was recorded using photoelectric cells (Witty, Microgate, Italy). The sprints were performed four times, separated by at least three minutes of passive recovery between each attempt. Time for each distance was recorded to the nearest 0.01 s, the best time for each test was recorded for the statistical analysis as used previously in adolescent (elite) soccer players (Buchheit et al., 2010). ***Figure 1*** shows the layout of the gate positions for the sprint test.



Drawing not to scale

Figure 1. Schematic diagram of test layout.

Change of Direction – 180º Test

Following a maximal sprint (protocol described previously), also described in the literature as a 'flying start', participants were asked to sprint forward to a turning point 5 m beyond the 20 m timing gate (25 m) and pivot 180°, the test was concluded when the participant re-broke the 20 m timing gate shown in ***Figure 1***. This test requires the participant to decelerate, change their body direction, by rotating 180°, and then accelerate. The test was repeated four times, with the turning foot alternated between their right and left foot, separated by at least three minutes of passive recovery between each test. Time was recorded using photoelectric cells (Witty, Microgate, Italy), to the nearest 0.01 s. A practitioner was positioned at the turning point, and if the participant turned prematurely, with the wrong foot, or slipped, the trial was discarded and subsequently another trial was performed after a further three minutes' rest. The fastest trial for the change of direction test was recorded for the statistical analysis as used previously in adolescent (elite) soccer players (Trecroci et al., 2019). ***Figure 1*** shows the layout of the gate positions for the change of direction test.

Countermovement Jump Test

The countermovement jump (CMJ) has previously been established to be a reliable measure of explosive power performance (Lloyd et al., 2009, Markovic et al., 2004). Following the maximal sprints, participants performed three jumps on a hard, flat surface between a portable photoelectric cell system (Optojump, Microgate, Bolzano, Italy), with 60 seconds of rest between trials. To isolate the lower limbs, and reduce the influence of technique and arm swing (Hara et al., 2008), participants were asked to keep their arms akimbo during CMJs. Participants were instructed to begin the jump from an initial standing position with a downward movement to a self-selected squat depth (Lloyd et al., 2009), which is immediately followed by a concentric upward movement, resulting in a maximal vertical jump (Lloyd et al., 2011). The final CMJ score was taken as the highest jump (cm) and used for statistical analysis as used previously in adolescent (elite) soccer players (Trecroci et al., 2019).

Reactive Strength Index

The reactive strength index (RSI) was determined using drop jump (DJ) tests, which involved the participants performing five separate jumps on a hard, flat surface between a portable photoelectric cell system (Optojump, Microgate, Bolzano, Italy). Participants performed DJs from a drop height of 0.30 m and were encouraged to use their hands during the jumps. Participants were asked to avoid stepping down or hopping from the box, and avoid tucking in the air (i.e. legs remain straight and attempt to land in the same position as take-off). Initially, participants stepped off the platform, dropped down to the floor, landed on both feet and then immediately jumped up as quickly and as high as possible. The aim of the jumps was to minimise the contact time, while attempting to maximize flight time (Flanagan and Comyns, 2008). Between DJs, a rest period of 60 seconds was given to avoid any residual fatigue effects (Read and Cisar, 2001). Every participant performed a practice jump for familiarisation. The dependent variables calculated for the jumps were contact time (CT) and flight time (FT). The RSI was calculated using ***Equation 1*** for each test. The best (highest) score was then selected as used previously in adolescent soccer players (Granacher et al., 2015).

Equation 1. Calculation of RSI.

$$RSI = \frac{FT}{CT}$$

An overall timeline for all test conditions and their duration are shown in ***Figure 2.***

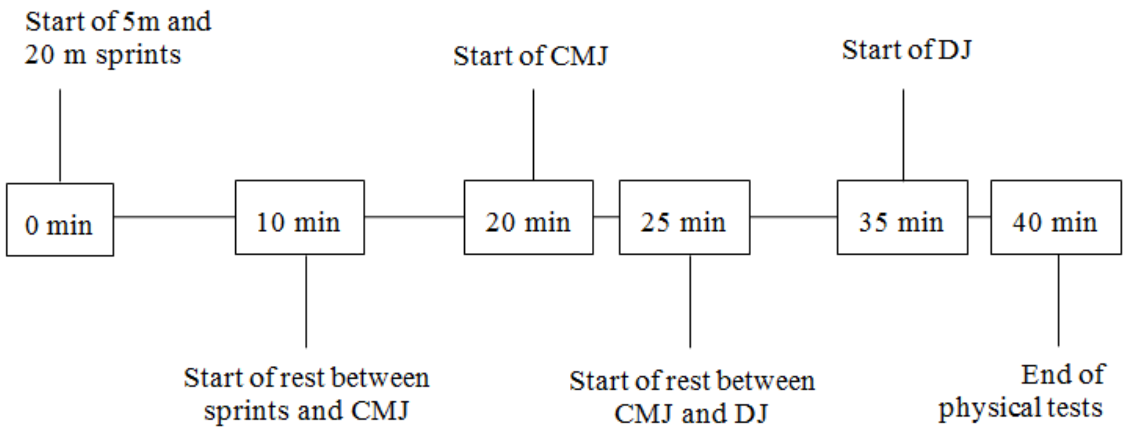


Figure 2. Breakdown of timeframes of test conditions during the study.Statistical Analyses

Descriptive statistics were calculated for the variables of interest, and were reported via mean and standard deviation (SD ±). Pearson product moment correlations were calculated for the following variables: estimated maturity status, percentage of predicted adult height, relative age, height (cm), weight (kg), chronological age (years), 5 m (s), 20 m (s), change of direction (s), CMJ (cm) and RSI. Hierarchical regression analysis was used to evaluate the main and interactive effects of relative age (decimal) and maturation (*z* - score) upon the performance parameters. Step 1 of the hierarchical regression analysis considered just the main effects of biological maturity and relative age, step 2 then also considered the interaction effect between these two variables. The process of centring (subtracting current score from group average) was used to create the interaction score (multiplying the centred scores) between biological maturity and relative age to reduce potential issues associated with collinearity. SPSS (IBM SPSS 24) was used for all analyses.

Results

Descriptive Statistics

The descriptive statistics for estimated biological maturity, predicted adult height, relative age, height, weight, and performance parameters, including 5 m, 20 m, change of direction, CMJ and RSI are presented in Table 1. The mean value for relative age was 0.67 years (i.e. Q2) across all age groups and did not appear to increase or decrease with age. Among the total sample of 84 participants, 43 participants (51%) were born in Q1, 22 participants (26%) were born in Q2, 11 participants (13%) were born in birth Q3, and 8 participants (10%) were born in Q4. A chi-squaread test ($\chi^2 = 35.9$, $p < 0.01$) indicates that there was an uneven distribution among the quartiles. The mean maturity z – score was either approximately zero or had a positive value in the U13 to U16 age groups. Only in the U12 age group was the maturity z-score below zero. Individuals that achieved a z - score of between –1 to +1 were classified as on–time in maturity status, if an individual achieved z – score greater than +1 were defined as early in maturity status, and if an individual achieved a z – score below than –1 they were defined as late in maturity status.

In terms of biological maturation, the majority of the participants (89%) fell within ±1.0 standard deviation of the reference mean for their sex and age. Whereas nine of the participants (11%) could be categorized as being advanced in maturation (i.e. >1.0 standard deviation above mean reference value for age and sex); no participants were considered late maturing (i.e. <1.0 standard deviation below mean reference value for age and sex).

Table 1. Descriptive statitiscics of participants per age group.

Variables	U12 (*n* = 24)		U13 (*n* = 19)		U14 (*n* = 21)		U15 (*n* = 8)		U16 (*n* = 12)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Chronological age	11.75	0.29	12.73	0.34	13.63	0.25	14.68	0.38	15.67	0.38
Height (cm)	150.20	6.40	160.70	8.69	162.20	8.30	175.20	6.70	176.40	6.74
Weight (kg)	39.2	4.30	45.90	8.10	48.10	6.20	63.10	8.30	63.50	7.20
Predicted adult height (cm)	182.4	5.30	185.7	6.3	180.5	7.1	183.5	2.7	182.2	4.9
Relative age	0.68	0.28	0.67	0.31	0.69	0.25	0.76	0.23	0.58	0.38
Maturity z - score'	-0.07	0.80	0.33	0.82	0.01	0.46	0.42	0.51	0.20	0.50
5 m sprint (s)	1.15	0.05	1.12	0.06	1.08	0.06	1.08	0.08	1.06	0.05
20 m sprint (s)	3.51	0.13	3.28	0.37	3.25	0.12	3.12	0.14	3.14	0.21
Change of direction (s)	2.58	0.14	2.36	0.07	2.27	0.09	2.24	0.06	2.21	0.13
CMJ (cm)	24.97	3.56	27.10	4.68	31.60	4.50	36.60	5.70	32.90	4.50
RSI	2.00	0.40	1.73	0.27	2.07	0.31	2.43	0.27	2.49	0.37

Where $\bar{x}$ is mean and SD is standard deviation.
Relative age was calculated as the difference between the participant's birthdate and the cut-off date (31st August). This was then divided by the number of days within the year (365 days).

Correlational Analyses

The results of the correlational analyses are summarised in ***Table 2.*** Of note, maturation was negatively correlated with 5 m, 20 m and change of direction test, indicating that players advanced in maturity status ran quicker over the set distances, and changed direction more quickly. Maturity was positively associated with performance on CMJ test, indicating that players advanced in maturation demonstrated greater prowess for jumping higher. Relative age was negatively associated with performance on the sprint test, but only at 20 m, and positively associated with performance on the CMJ test. Maturity correlations were statistically significant at $p < 0.01$ and relative age was statistically significant at $p < 0.05$.

Table 2. *R* values for correlational analyses between various anthropometric, maturity, and fitness parameters.

Variables	CA	BA	Maturity ‘*z*’	RA	Height	Weight	PAH	5 m	20 m	COD	CMJ	RSI
CA	-											
BA	.92**	-										
Maturity ‘z’	.19*	0.52**	-									
RA	.11	0.13	-0.04	-								
Height	.78**	0.90**	0.59**	0.14	-							
Weight	.81**	0.88**	0.46**	0.17	0.90**	-						
PAH	-.03	0.10	0.36**	0.06	0.53**	0.35**	-					
5 m sprint	-.65**	-0.68**	-0.35**	-0.08	-0.61**	-0.58**	-0.08	-				
20 m sprint	-.61**	-0.64**	-0.32**	-0.19*	-0.60**	-0.58**	-0.10	0.66**	-			
COD	-.77**	-0.75**	-0.33**	-0.08	-0.64**	-0.60**	0.02	0.66**	0.61**	-		
CMJ	.70**	0.71**	0.32**	0.23*	0.62**	0.67**	0.01	-0.62**	-0.65**	-0.60**	-	
RSI	.58**	0.47**	-0.06	0.05	0.31**	0.43**	-0.23*	-0.36**	-0.37**	-0.42**	0.46**	-

*Correlation is significant at the 0.05 level (1-tailed).

** Correlation is significant at the 0.01 level (1-tailed).

CA – Chronological age; BA – Biological age; RA – Relative age; PAH – Predicted adult height; COD – Change of direction.

Regression Analysis

The results for each hierarchical regression model for the different performance variables are presented in Table 3-7.

The final regression model for 5 m sprint times achieved statistical significance, $F\,(3, 79) = 4.57$, $p < 0.01$, (***Table 3***). In the final model, maturation served as a statistically significant negative predictor of time in both the main and interactive model. Relative age and the interaction between relative age and maturation did not predict any of the variance in sprint performance over 5 m.

Table 3. Summary of hierarchical regression analysis for variables predicting 5 m (s) sprint time.

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Maturity Status (MS)	- 0.03	0.01	- 0.35**	-0.07	0.03	- 0.74**
Relative Age (RA)	- 0.02	0.02	- 0.10	-0.01	0.02	- 0.05
Interaction MS x RA				0.04	0.30	0.42
R2	0.13			0.15		
F for change in R2	5.93			4.57		

*$p < 0.05$.
**$p < 0.01$.

The results for the regression model predicting variance in performance in the 20 m sprint task are presented in ***Table 4***. The final model was statistically significant, $F\,(3, 79) = 4.62$, $p < 0.01$. As with the 5 m sprint test, a main effect was observed for maturity but not relative age or the interaction term, although maturity status only had an effect in the main model. More specifically, maturation was inversely associated with 20 m sprint time.

Table 4. Summary of hierarchical regression analysis for variables predicting 20 m (s) sprint time.

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Maturity Status (MS)	- 0.13	0.39	- 0.33**	-0.17	0.12	- 0.47**
Relative Age (RA)	- 0.17	0.86	- 0.21	-0.16	0.09	-0.19
Interaction MS x RA				0.05	0.11	0.14
R2	0.15			0.15		
F for change in R2	6.90			4.62		

*$p < 0.05$.
**$p < 0.01$.

The regression model for change of direction times was also statistically significant, $F\,(3, 80) = 3.83$, $p < 0.05$, (***Table 5***). Statistically significant main effects were observed for maturity in the main model, however, relative age and the interaction term did not serve as significant predictors in the models. Maturation was inversely associated with change of direction times, indicating superior performance in more mature and relatively older players.

Table 5. Summary of hierarchical regression analysis for variables predicting change of direction (s) ability.

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Maturity Status (MS)	- 0.08	0.02	-0.34^{**}	-0.14	0.07	-0.63^{**}
Relative Age (RA)	- 0.05	0.05	- 0.09	-0.27	0.06	- 0.05
Interaction MS x RA				0.07	0.07	0.32
R^2	0.12			0.13		
F for change in R^2	5.29			3.83		

$^{*}p < 0.05$.
$^{**}p < 0.01$.

The regression model for CMJ was also statistically significant, F (3, 77) = 5.32, $p < 0.05$, (***Table 6***). Again maturity was shown to be significant for CMJ in the main model. Unlike for the previous tests, the main and interaction effects revealed a statistically significant effect for relative age. The interaction term for maturity and relative age was shown to be non-significant. Specifically, maturation was positively associated with CMJ heights indicating an athletic advantage associated with advanced maturation. Equally, relative age showed a positive association; participants born earlier in the selection year showed improved performance.

Table 6. Summary of hierarchical regression analysis for variables predicting CMJ (cm) ability.

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Maturity Status (MS)	2.80	0.86	0.33^{**}	3.82	2.58	0.45^{**}
Relative Age (RA)	4.65	1.94	0.24^{**}	4.34	2.09	0.23^{*}
Interaction MS x RA				-1.06	2.53	-0.13
R^2	0.16			0.17		
F for change in R^2	7.97			5.32		

$^{*}p < 0.05$.
$^{**}p < 0.01$.

In contrast, the regression model for RSI did not achieve statistical significance, F (3, 71) = 0.32, $p > 0.05$, (***Table 7***). Inspection of the main and interaction effects revealed there was no statistically significant association between predictor variables and RSI performance.

Table 7. Summary of hierarchical regression analysis for variables predicting RSI ability.

Variable	Model 1			Model 2		
	B	SE B	β	B	SE B	β
Maturity Status (MS)	- 0.04	0.08	- 0.06	0.13	0.25	0.18
Relative Age (RA)	0.08	0.18	0.05	0.03	0.19	0.02
Interaction MS x RA				- 0.18	0.25	- 0.26
R^2	0.01			0.01		
F for change in R^2	0.22			0.32		

$^{*}p < 0.05$.
$^{**}p < 0.01$.

Discussion

The purpose of this study was to investigate the main and interactive effects of maturity status and relative age upon physical performance in a series of fitness tests amongst a sample of 84 professional academy soccer players. It was found that the interactive effect of maturity status and relative age was small therefore showing that these are two independent constructs that must be treated separately when considering the development of male adolescent soccer players. Maturity status was shown to have a much greater influence on performance which should be accounted for when considering soccer players of the same chronological age.

Consistent with previous literature (Helsen et al., 2005, Sierra-Díaz et al., 2017, Musch and Grondin, 2001a), participants in the current study tended to be relatively older for their age group and average-to-advanced in biological maturity. The majority of participants (77%) were born in the first half of their competitive year, with more than half of the total participants being born in the first birth quarter (51%). Collectively, these values suggested the presence of a strong RAE that is present from late childhood and maintained throughout the academy structure. This observation is of concern as previous research suggests that late maturing and / or younger players, though under-represented in youth soccer, are psychologically and technically more proficient than their peers (Zuber et al., 2016, Cumming et al., 2018b, Votteler and Höner, 2014). The cause of this trend could be attributed to a need for less physically developed players to exemplify better technical and / or psychological ability in order to compete with early maturing individuals. Alternatively, this could be a feature of selection where coaches will only prefer a less physically developed player if their technical and / or psychological skills are already much advanced in comparison to physically developed individuals.

The results of the current investigation are consistent with previous research within youth soccer which has used skeletal age as an indicator of maturity status, whereby advanced maturity status appeared to act as a positive predictor of persistence, selection and retention (Carling et al., 2012, Johnson et al., 2017, Malina et al., 2015). Moreover, further research is needed in order to understand the nature of the bias and redress the situation that is present where talented but late maturing players are being omitted from an academy system.

The results pertaining to the associations between biological maturity, relative age and physical fitness are of particular interest (Table 3-7). First, it is important to note that biological maturity and relative age were found to be unrelated. This supports the contention that biological maturity and relative age are constructs or processes that exist and operate independently of one another. Accordingly, RAE cannot be attributed to the functional advantages that are associated with advanced biological maturation, which typically emerges around the onset of puberty (Johnson et al., 2017). It should be noted, however, that within this sample, relative age was found to present a positive, yet weak and non-significant association with height and weight. Thus, RAE may be more likely to be associated with individual differences in growth than maturation, per se. To better understand and counter the selection biases associated with relative age and biological maturation it is important that researchers and practitioners recognise the differences between these constructs. As noted, the selection biases associated with biological maturity and relative age emerge at different ages and it is likely that the mechanisms underpinning these biases are also different. Therefore, strategies designed to address and minimise the selection-induced RAE (e.g. average team age competitions, implementation of quotas for even representation of children of all birth months and age-ordered shirts) should focus on developmental attributes more closely associated with age rather than maturity (i.e. cognition, motor skills, and experience) and may need to be introduced from an earlier age and at the grass roots level. In contrast, strategies designed to address maturity selection biases (e.g. bio-banding) are better reserved for late childhood and early puberty, when maturity associated differences in size and function become much more salient.

Contrary to expectations, relative age was found to be largely unrelated to measure of physical fitness. That is, relatively older players did not appear to perform any better on tests of speed, strength, and power than their younger peers. With respect to the correlational analyses (Table 2), relative age was only significantly associated with performance on the 20 m sprint and the CMJ tests. Older players did perform better on these tests, however, the magnitude of the associations was weak to moderate. In contrast, maturation was associated with performance on all but one of the physical performance tests (RSI). Specifically, advanced maturation was associated with superior performance on tests of speed, change of direction and CMJ. The magnitude of these associations was moderate and notably greater than those equivalent values observed for relative age. The results of the regression models provided further insight into the main and interactive effects of biological maturation and relative age upon performance on the physical tests. With the exception of the RSI test, all of the regression models were statistically significant. Maturation served as a statistically significant and positive predictor of performance in the 5 m and 20 m sprint tests, the change of direction test, and the CMJ test. In contrast, relative age only served as a significant predictor of performance on the CMJ. The interaction between biological maturation and relative age failed to serve as a significant predictor of performance on all of the fitness tests. Collectively, these results suggest physical fitness in academy soccer players is more likely to be associated with variance in biological maturity rather than relative age. Such selection biases are more likely to result from age related differences in other developmental attributes such as experience, motor skills, and cognitive and / or social skills (Cumming et al., 2018b). The results of the current study also suggest that maturation and relative age do not interact to influence fitness within this cohort. That is, being relatively older or younger within one's age group appears to have little to no bearing on the fitness performances of players who are advanced or delayed in maturation.

The fact that RAE has an influence on CMJ is interesting. The countermovement jump is a lower limb power test which is a fundamental variable for performance in soccer and therefore the fact that this influenced by RAE is of significant importance to the conclusion of this study. While other tests (e.g. speed, change of direction and transfer of power [RSI]) were not affected by RAE, it can not be completely discounted from discussions around performance within a soccer setting.

The results of this investigation have important practical implications for those involved in the identification and development of talented young male soccer players. From a talent identification perspective, it is important to note that players who are advanced in biological maturity for their age group will possess a significant advantage in terms of their physical fitness (Deprez et al., 2015). As a consequence, players who mature early may perform better during competitions and on tests of physical aptitude. Technically gifted yet later maturing players are physically disadvantaged and may struggle to compete when matched against physically more able peers. As a consequence late maturing players may be more likely to be overlooked or excluded from the academy system. From a developmental perspective, players who mature in advance of their peers may also be more likely to play to their physical strengths, neglecting their technical, tactical and psychological skills (Cumming et al., 2018a). While such a strategy may bring immediate success, its value in the long term is limited as maturity associated differences in size and function are typically attenuated, and in some cases reversed, in early adulthood. Through being side-lined or as a result of the magnitude of these differences, late maturing players may have less opportunity to apply, demonstrate or develop these skills, regardless of ability (Cobley, 2016). To address the aforementioned concerns it is important that coaches and practitioners both recognise and become aware of individual differences in players' maturation. Individual differences in biological maturity status have been shown to directly and indirectly influence player performance and selection in youth football (Cumming et al., 2017). The results of the current study highlight the significant role of individual differences in biological maturity status in the physical performance capacity of adolescent soccer players. Recently the English Premier League has trialled the practice of bio-banding whereby players within a specific chronological age group are banded by estimated maturity status in an effort to balance maturity associated differences in size and function. In order to individualise the selection and training processes, the Royal Belgian Football Association distinguish players based on their developmental age, rather than birth year (Philippaerts et al., 2004, Vandendriessche et al., 2012). However, there can be advantages for late developers mixing with players of different biological ages. The late developers will face challenges and will need to adapt technically, tactically and mentally; these challenges will be missed if they only practice with players of a similar developmental age (Wormhoudt et al., 2017).

There are several limitations of the current study that should be highlighted. First of all, the results of the present study are restricted to one single soccer academy and therefore may not be generalizable and relative to other academy settings and games programmes. Secondly, parental heights, which were used for the estimation of biological maturity status, were largely self-reported, and reference values used to estimate the z - scores were based only on European (Caucasian) ancestry, yet this group includes non-Caucasian participants. A further limitation is that the study only considered tests of physical performance; results for the influence of biological maturity status and RAE may be different for tests, for example social, psychological, technical and tactical factors. For example, Cumming et al. (2018b) shown that maturity status had a strong correlation with psychological factors such as self-regulated learning.

It should also be noted that the participants in this present study in terms of both of biological maturity status and RAE were not evenly distributed. Less than 10% of participants were born in Q4, whereas 51% were born in Q1. A more balanced distribution may have shown stronger correlations between RAE and physical performance tests; and it may be possible that there is preferential deselection of the weakest Q4 participants. Only nine of the participants were early maturers, and there were no late maturers in the selection sample, hence some of the correlations between maturity status and physical performance tests may be diluted as the majority of participants fell within ±1.0 standard deviations of the average for their age. Note that the current study included nine goalkeepers (11%) who may be expected to experience a different performance profile to that of an outfield player - a larger study in the future may be able to account for this. However, ***Table 8*** compares the means between both the outfielders and goalkeepers in the present study. Goalkeepers were older, taller and weighed more with a small to medium effect size ($p > 0.05$, Cohen's $d = 0.35$, $d = 0.40$ and $d = 0.51$, respectively) than outfield players. Moreover, outfield players outperformed the goalkeepers in all of the physical performance tests with a small to medium effect size; 5 m, $p < 0.05$, $d = 0.42$; 20 m, $p > 0.05$, $d = 0.38$; COD, $p > 0.05$, $d = 0.35$; CMJ, $p > 0.05$, $d = 0.07$ and RSI, $p > 0.05$, $d = 0.24$.

Table 8. Descriptive variables and comparisons of positional means ± SD in physical performance tests between outfielders and goalkeepers.

	Outfielders	Goalkeepers
CA (years)	13.24 ± 1.36	13.73 ± 1.52
Height (cm)	161.1 ± 11.7	165.9 ± 12.1
Weight (cm)	48.0 ± 10.9	53.5 ± 10.6
5 m (s)	1.11 ± 0.10*	1.15 ± 0.09
20 m (s)	3.33 ± 0.25	3.43 0.27
COD (S)	2.34 ± 0.17	2.40 ± 0.17
CMJ (cm)	29.4 ± 5.64	29.0 ± 6.02
RSI	2.10 ± 0.37	2.02 ± 0.30

Note: CA = Chronological age; COD = Change of direction; CMJ – Countermovement jump; RSI – Reactive strength index. *$p < 0.05$, difference between outfielders and goalkeepers.

This study has found that physical performance in the tests studied was seen to be related to the biological maturity status of a player. Relative age was only seen to have an influence in one performance test (CMJ), which is strongly related to this sport. The influence of RAE is much less significant than biological maturity status but may be an important secondary factor in some instances. Coaches and practitioners should be aware of this and can use this information to be better informed of the relative performance of the players within their academy. Further longitudinal research is required to assess the role of physical performance in relation to player retention and deselection, including the impact of non-physical parameters in this process. Other studies that may advance this work could be to investigate the influence of differences between academy settings, for example the impact of a January - December rather than September - August selection year may have on the relationship between RAE and physical performance tests. A further major advance would be made by making a similar assessment of biological maturation and relative age on actual match performance rather than training data, as match performance is arguably more important and has a different set of motivational and environmental influences.

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