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The role of biological maturation and relative age in player selection during transition phases at a German youth football academy

Introduction

Talent identification, selection, and development in youth football academies are central processes in the cultivation of future elite players (Ford et al., 2020; Williams, Ford, & Drust, 2020). Player development is typically supported by a multidisciplinary team comprising coaches, sport scientists, strength and conditioning coaches, physiotherapists, medical practitioners, psychologists, and pedagogues, all working within a structured system designed to maximise players' potential as they progress towards professional football (Richardson, Gilbourne, & Littlewood, 2004). However, talent development pathways are rarely linear, with both selection and deselection occurring frequently throughout the developmental process (Güllich, 2014; Williams et al., 2020), particularly within youth academy environments (Bidaurrezaga-Letona, Lekue, Amado, & Gil, 2019; Dugdale, McRobert, & Unnithan, 2021b; Figueiredo, Gonçalves, Coelho-e-Silva, & Malina, 2009; Platvoet, Opstoel, Pion, Elferink-Gemser, & Visscher, 2020).

Selection (i.e., the ongoing process of identifying players within a talent promotion programme who demonstrate

attributes considered conducive to progression to a higher squad or team) and deselection (i.e., the removal of players from the development pathway who are no longer perceived to possess the attributes required for continued progression) are influenced by a complex interplay of factors (Williams et al., 2020; Williams & Reilly, 2000). Evidence suggests that selected players consistently outperform their deselected counterparts across a range of skill-related attributes, including decision-making, dribbling ability, and game intelligence, as well as psychological characteristics such as concentration and creativity (Dugdale et al., 2021b; Huijgen, Elferink-Gemser, Lemmink, & Visscher, 2014; Platvoet et al., 2020). Furthermore, selected players generally demonstrate superior physical capacities, including aerobic fitness, explosive power, and sprint performance (Bidaurrezaga-Letona et al., 2019; Figueiredo et al., 2009; Platvoet et al., 2020). In contrast, differences in anthropometric characteristics, such as stature and body mass, tend to be less pronounced between selected and deselected players (Bidaurrezaga-Letona et al., 2019; Dugdale et al., 2021b).

Biological maturation and relative age have been identified as important,

non-modifiable factors that may influence physical performance and talent identification strategies in youth football research (Hill, Scott, Malina, McGee, & Cumming, 2020a; Leyhr et al., 2021; Parr et al., 2020; Sweeney & Lundberg, 2024; Unnithan, White, Georgiou, Iga, & Drust, 2012; Williams et al., 2020). Biological maturation refers to the progression towards the mature biological state across tissues, organs, and physiological systems (Malina, Rogol, Cumming, Coelho-e-Silva, & Figueiredo, 2015). It can be described in terms of maturity status, which reflects an individual's current state of maturation, and maturity timing, which reflects the age at which specific maturational events occur (Cumming, Lloyd, Oliver, Eisenmann, & Malina, 2017; Malina et al., 2019). Because processes of biological maturation and chronological age do not necessarily progress in parallel, academy players of the same chronological age may differ by as much as 5–6 years in indicators of maturity status (e.g., skeletal age) (Leyhr, Murr, Hirte, & Höner, 2025; Malina et al., 2000).

More biologically mature players are often favoured during selection processes, as they typically possess advanced anthropometric characteristics

(e.g., greater body mass and stature) and superior physical capacities, including aerobic and anaerobic fitness (Coelho e Silva et al., 2010; Lloyd, Oliver, Faigenbaum, Myer, & De Ste Croix, 2014). This phenomenon has been termed maturity-related selection bias (Hill et al., 2020a; Sweeney & Lundberg, 2024). Evidence suggests that such bias begins to emerge around 11–12 years of age and becomes increasingly pronounced with advancing age, higher competitive standards, and specific playing positions (Curnyn, Leslie, Palmer, Williams, & Cumming, 2025; Hill et al., 2020a; Johnson, Farooq, & Whiteley, 2017; Leyhr et al., 2025). For example, regional-level U14 players have been shown to exhibit a higher maturity status, larger anthropometric characteristics, and superior physical performance than their non-selected counterparts (Coelho e Silva et al., 2010). Consequently, it is unsurprising that players aged 13–14 years with a higher maturity status are more likely to be recruited into elite youth academies (Figueiredo et al., 2009). Supporting this notion, a higher maturity status has been identified as a positive predictor of both player selection and continued participation within youth football promotion programmes (Bidaurrazaga-Letona et al., 2019).

Another well-documented selection phenomenon in youth football is the Relative Age Effect (RAE), which arises from age differences among players within the same chronological cohort and often results in an overrepresentation of individuals born earlier in the selection year (Helsen, Winckel, & Williams, 2005). These players are frequently perceived as more physically developed; however, empirical evidence indicates that anthropometric and physical advantages associated with relative age are generally small and inconsistent, varying according to playing position, competition level, and age group (Bozděch, Agricola, & Zháněl, 2023; Brustio et al., 2018; Dugdale, McRobert, & Unnithan, 2021a). Moreover, the magnitude of the RAE appears to decline at senior levels of competition (Bozděch et al., 2023; Doncaster et al., 2024; Dugdale et al., 2021a).

Although maturity-related and relative age selection biases may coexist, they are considered distinct mechanisms (Towlson, MacMaster, Parr, & Cumming, 2022). Relative age is determined by an individual's birth date within a selection year, whereas maturity-related selection bias reflects variation in biological maturation among players of similar chronological age (Hill et al., 2020a; Towlson et al., 2022). This distinction is reflected in their differing developmental trajectories. The RAE typically emerges during early childhood and remains relatively stable throughout adolescence, whereas maturity-related selection bias becomes increasingly influential around the onset of puberty, when inter-individual variation in biological maturation becomes more pronounced (Bozděch et al., 2023; Johnson et al., 2017). Consequently, the common assumption that relatively older players are inherently more biologically mature is not supported by the available evidence (Hill et al., 2020a; Peñín-Grandes, Mesonero-García, Huertas Olmedo, Ginés Cabeza, & Ballester Lengua, 2025; Sweeney, Cumming, MacNamara, & Horan, 2023; Towlson et al., 2022). For example, an even distribution of skeletal maturity status across birth quarters has been reported in academy players aged 11–14 years (Figueiredo, Coelho-e-Silva, Cumming, & Malina, 2019) while only moderate associations between somatic maturity status and relative age were observed in a large-scale study conducted by the Swedish Football Association (Sweeney & Lundberg, 2024). Furthermore, recent evidence from Scottish youth football reported no association between relative age and biological age, reinforcing the notion that relatively older players are not necessarily more biologically mature than their younger counterparts, despite the presence of a RAE (Curnyn et al., 2025).

Despite growing interest in both maturity-related selection bias and the RAE, the available literature remains limited. Most previous investigations have focused on cohorts of already selected academy players (Hill, Scott, Malina, McGee, & Cumming, 2020b; Sweeney et al., 2023), thereby examining the

outcomes of selection processes rather than the transition periods during which such biases may influence selection decisions. Consequently, the extent to which maturity status and relative age affect player progression between age categories within an established youth academy remains insufficiently understood. To address this gap, the present study examined the influence of maturity status and relative age on progression decisions within a German youth football academy. In addition, the association between maturity status and relative age was investigated across successive age-group transitions. It was hypothesised that relative age effects would be evident across age groups, whereas maturity-related selection bias would become increasingly pronounced during adolescence. Furthermore, small associations were expected between maturity status and relative age.

Material and methods

Participants

The study sample comprised male football players ($n=176$) from the U12–U15 age groups of the youth academy of a professional German club whose senior team competed in the 2nd Bundesliga. All academy teams competed at the highest level of their respective age categories. Players and guardians were informed that anthropometric and additional data would be collected during routine academy assessments, with voluntary participation and the option to withdraw at any time. Written informed consent was obtained from guardians, and assent was provided by the players. Data were anonymized prior to analysis, and retrospective use was approved by the ethics committee of Friedrich-Alexander-University Erlangen-Nuremberg (approval no. 25-207-Sr).

Procedure

A retrospective analysis of prospectively collected cohort data was conducted over five consecutive seasons (2020/21–2024/25). For U12–U15 age groups, seasons ran from September to August,

with progression decisions to the next age category typically made in April or May by the youth academy's technical director and incoming coaches.

Players' maturity status was assessed four times per season using maturity offset (MO): pre-season (August), mid-season (November), post-winter break (February), and end of season (April). To capture the most recent maturity information available at the time selection decisions were made, MO estimates obtained during the final assessment in April were used for the primary analyses. To evaluate the robustness of this approach, sensitivity analyses were conducted using MO estimates derived from the August, November, and February assessments. Applying identical statistical procedures yielded comparable results across all assessment time points (August: $p = 0.11$, OR = 1.19, 95% CI = 0.97–1.62; November: $p = 0.041$, OR = 1.36, 95% CI = 1.02–1.75; February: $p = 0.023$, OR = 1.47, 95% CI = 1.07–2.03), indicating that the observed association between maturity status and selection outcomes was not dependent on the timing of the assessment. Relative age was also determined for each player. Detailed assessment procedures for both variables are described in the following sections.

Biological maturation

Standing height, sitting height, and body mass were assessed using the academy's standardised testing procedures. Standing and sitting height were measured to the nearest 0.1 cm using a stadiometer (Seca 217, Hamburg, Germany), with standing height assessed in the Frankfurt plane. Body mass was measured to the nearest 0.1 kg using a calibrated digital scale (Seca 769, Hamburg, Germany), with players barefoot and wearing light clothing. All anthropometric assessments were conducted by experienced practitioners from the club's sport science department.

Maturity status was estimated using the maturity offset (MO) equation developed by Mirwald, Baxter-Jones, Bailey, and Beunen (2002). This non-invasive, field-based method predicts the number of years an individual is from peak height

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The role of biological maturation and relative age in player selection during transition phases at a German youth football academy

Abstract

This study investigated the influence of biological maturation and relative age on player selection during transition phases in a German youth football academy. In addition, it examined the extent to which biological maturation and relative age were correlated among selected players. A total of 176 male football players (U12–U15), competing in their highest age-specific league, were assessed for maturity offset and relative age across four sessions per season (2020/21–2024/25). Progression to the subsequent age group was examined using penalized logistic regression models, while associations between maturity offset and relative age were evaluated using Spearman's rank correlation coefficients. Regression analyses revealed no significant effects in the pooled sample; however, age-specific analyses identified significant maturity-related selection biases during the U14 → U15 (OR = 2.26, $p = 0.026$) and U15 → U16 (OR = 1.95, $p = 0.042$) transitions. Relative age

was not a significant predictor of progression at any transition. Moderate negative associations between maturity offset and relative age were observed following the U12 ($\rho = -0.47$) and U13 ($\rho = -0.37$) transitions, whereas weaker associations were found following the U14 ($\rho = -0.32$) and U15 ($\rho = -0.27$) transitions. These findings indicate that progression decisions within the academy are influenced more strongly by maturity status than by relative age, particularly during the transition phases following the U14 and U15 seasons. Furthermore, the observed correlations indicate that maturity status and relative age are related, yet distinct, constructs whose association decreases with increasing age and therefore warrant separate consideration within talent pathways.

Keywords

Soccer · Talent development · Maturation · Selection · Relative age

velocity (PHV) based on standing height, sitting height, leg length, body mass, and chronological age. The method is widely used in youth athlete research owing to its practicality, low cost, and acceptable validity (Towlson et al., 2021). For boys, a standard error of estimate of approximately 0.59 years, with a 95% confidence interval (CI) of ± 1.0 year is reported (Mirwald et al., 2002).

Relative age

Relative age was calculated as the player's day of birth within the calendar year, consistent with previous research (Leyhr, Rösch, Cumming, & Höner, 2024). Accordingly, a player born on 1 January was assigned a relative age value of 1, whereas a player born on 31 December was assigned a value of 365.

Statistical analysis

Data were organized in Microsoft Excel (Microsoft Corporation, Redmond, USA, Version 2108) and analysed in RStudio (Posit Software, PBC, Boston, MA, USA, Version 2024.12.1.563). Descriptive statistics (mean $\pm$ SD) were calculated for anthropometric measures (e.g., weight, height), biological maturation variables (e.g., MO, age of peak height velocity), and age-related variables (e.g., chronological age, relative age). Normality of continuous variables was assessed using the Shapiro–Wilk test, and homogeneity of variances via Levene's test. Linearity and distributional assumptions for correlation analyses were checked visually, and multicollinearity in logistic regression models was assessed using variance inflation factors (VIF), with a VIF > 10 considered indicative of multicollinearity (Akinwande, Dikko, & Samson, 2015).

Table 1 Descriptive statistics for the total sample and selected/deselected players across age-group transitions

Transition	Group	Number of observations	RA (decimal)	CA (years)	Weight (kg)	Height (m)	MO (years)	APHV (years)
Overall	All	376	133.35 ± 90.88	12.68 ± 1.17	51.20 ± 11.03	1.63 ± 0.12	-0.23 ± 1.26	12.92 ± 0.72
	Selected	328	131.31 ± 91.06	12.65 ± 1.16	51.24 ± 10.97	1.63 ± 0.11	-0.23 ± 1.27	12.88 ± 0.69
	Deselected	48	147.31 ± 89.37	12.93 ± 1.18	50.96 ± 11.52	1.63 ± 0.12	-0.23 ± 1.17	13.14 ± 0.89
U12 to U13	All	81	122.46 ± 88.37	11.15 ± 0.47	41.45 ± 6.03	1.52 ± 0.08	-1.70 ± 0.54	12.85 ± 0.50
	Selected	75	124.39 ± 89.96	11.16 ± 0.48	41.49 ± 6.20	1.52 ± 0.08	-1.70 ± 0.55	12.86 ± 0.51
	Deselected	6	98.33 ± 66.49	11.02 ± 0.18	40.95 ± 3.52	1.52 ± 0.05	-1.64 ± 0.52	12.66 ± 0.39
U13 to U14	All	97	128.75 ± 89.49	12.12 ± 0.44	47.19 ± 8.43	1.60 ± 0.09	-0.80 ± 0.66	12.93 ± 0.66
	Selected	87	128.87 ± 90.21	12.14 ± 0.45	47.21 ± 8.12	1.60 ± 0.09	-0.79 ± 0.63	12.94 ± 0.65
	Deselected	10	127.70 ± 87.57	11.94 ± 0.24	47.03 ± 11.29	1.58 ± 0.12	-0.87 ± 0.85	12.81 ± 0.76
U14 to U15	All	100	138.21 ± 90.75	13.11 ± 0.47	53.88 ± 9.45	1.67 ± 0.10	0.14 ± 0.80	12.97 ± 0.85
	Selected	84	136.58 ± 93.28	13.13 ± 0.49	54.63 ± 9.26	1.68 ± 0.09	0.22 ± 0.77	12.91 ± 0.83
	Deselected	16	146.75 ± 78.14	13.01 ± 0.35	49.91 ± 9.71	1.62 ± 0.13	-0.27 ± 0.86	13.28 ± 0.87
U15 to U16	All	98	141.96 ± 94.56	14.07 ± 0.49	60.51 ± 9.39	1.72 ± 0.08	1.17 ± 0.76	12.91 ± 0.79
	Selected	82	134.83 ± 91.83	14.05 ± 0.46	60.95 ± 8.93	1.73 ± 0.08	1.25 ± 0.69	12.82 ± 0.70
	Deselected	16	178.50 ± 102.90	14.17 ± 0.64	58.23 ± 11.53	1.72 ± 0.08	0.74 ± 0.99	13.39 ± 1.03

Values are presented as mean ± standard deviation

APHV age at peak height velocity, CA chronological age, MO maturity offset, RA relative age

Table 2 Results of logistic regression models

Model	Number of observations	Predictor	Estimate	SE	Z	p	OR	95% CI	Nagelkerke R ²	χ ²	Df	Model p
Overall	376	MO	-0.02	0.12	-0.13	0.897	0.98	0.77–1.25	0.11	1.34	2	0.513
Overall		Relative age	-0.00	0.00	-1.17	0.248	1.00	0.99–1.00				
U12 to U13	81	MO	0.02	0.78	0.03	0.979	1.02	0.21–5.75	0.12	0.38	2	0.827
U12 to U13		Relative age	0.00	0.01	0.58	0.576	1.00	0.99–1.02				
U13 to U14	97	MO	0.19	0.52	0.36	0.729	1.20	0.43–3.63	0.10	0.12	2	0.941
U13 to U14		Relative age	0.00	0.00	0.10	0.919	1.00	0.99–1.01				
U14 to U15	100	MO	0.82	0.38	2.17	<i>0.026</i>	2.26	1.10–5.01	0.20	5.12	2	0.077
U14 to U15		Relative age	0.00	0.00	0.29	0.774	1.00	0.99–1.01				
U15 to U16	98	MO	0.67	0.32	2.06	<i>0.042</i>	1.95	1.02–3.80	0.23	6.94	2	0.031
U15 to U16		Relative age	-0.00	0.00	-1.22	0.225	1.00	0.99–1.00				

Significant predictors ($p < 0.05$) are presented in *italics*

MO maturity offset, OR odds ratio, CI confidence interval

To examine the influence of MO and relative age on progression decisions (selected = 1, deselected = 0), penalized binary logistic regression models using Firth's bias-reduced maximum likelihood estimation were fitted (Rahman & Sultana, 2017). Analyses were conducted for the pooled sample and separately for each age-group transition (U12 → U13, U13 → U14, U14 → U15, and U15 → U16). MO and relative age were entered simultaneously as predictors. Model performance was evaluated using Nagelkerke's pseudo-R², whereas overall model significance was assessed using likelihood-ratio χ^2 tests comparing

the fitted models against intercept-only models.

Associations between MO and relative age were examined using Spearman's rank-order correlation coefficients (ρ), as variables deviated from normality. Correlation analyses were performed separately for each age-group transition using continuous MO values and decimal relative age values. Correlation magnitudes were interpreted as trivial (0.00–0.09), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), and nearly perfect (0.90–1.00) (Hopkins, 2002). Statistical significance was set at $p < 0.05$ for all analyses.

Results

Across the study period, 48 players were classified as deselected (12.8%), with deselection rates highest following the U14 and U15 transitions (both $n = 16$; 16.0% and 16.3%, respectively), followed by U13 ($n = 10$; 10.3%) and U12 ($n = 6$; 7.4%). Descriptive statistics for the overall sample and stratified by selection status within each transition are presented in [Table 1](#).

Results of the regression analyses are presented in [Table 2](#). The pooled model was not significant ($\chi^2 = 1.34$, $p = 0.513$) and explained little variance in progres-

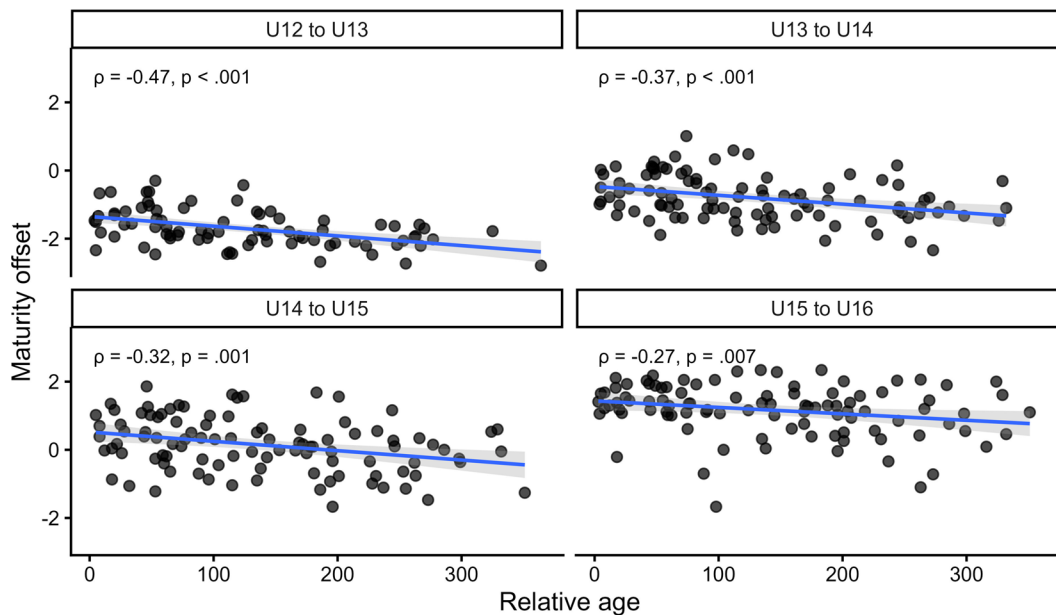


Fig. 1 Relationship between relative age and maturity offset across age-group transitions (Points represent individual player observations, and solid lines represent fitted linear regression trends with 95% confidence intervals.)

sion outcomes (Nagelkerke's $R^2 = 0.11$). Neither MO (MO: $\beta = -0.02$, $p = 0.897$; OR = 0.98, 95% CI: 0.77–1.25) nor relative age ($\beta < 0.01$, $p = 0.248$; OR = 1.00, 95% CI: 0.99–1.00) significantly predicted progression when all transitions were considered jointly.

Age-specific analyses revealed no significant effects of MO or relative age for the U12 → U13 ($\chi^2 = 0.38$, $p = 0.827$; Nagelkerke's $R^2 = 0.12$) or U13 → U14 ($\chi^2 = 0.12$, $p = 0.941$; Nagelkerke's $R^2 = 0.1$) transitions. For the U14 → U15 transition, higher MO values were associated with an increased likelihood of progression ($\beta = 0.82$, $p = 0.026$; OR = 2.26, 95% CI: 1.10–5.01). Similarly, MO significantly predicted progression from U15 → U16 ($\beta = 0.67$, $p = 0.042$; OR = 1.95, 95% CI: 1.02–3.80). Relative age was not a significant predictor in any age-group transition.

Figure 1 illustrates the association between MO and relative age across age-group transitions. Spearman's rank correlations revealed moderate negative associations following U12 ($\rho = -0.47$, 95% CI: -0.62 , -0.28 , $p < 0.001$) and U13 ($\rho = -0.37$, 95% CI: -0.52 , -0.20 , $p < 0.001$). Smaller negative associations were observed following U14 ($\rho = -0.32$, 95% CI: -0.49 , -0.13 , $p = 0.001$) and U15 ($\rho = -0.27$, 95% CI: -0.45 , -0.07 , $p = 0.007$).

Discussion

This study examined the influence of maturity status, estimated using MO, and relative age on player selection during seasonal transitions within a youth football academy (U12–U15). Consistent with our hypothesis, maturity-related selection bias was not evident in the younger age groups but emerged during adolescence. Significant effects of maturity status were observed during both the U14 → U15 and U15 → U16 transitions, with the strongest association identified for the U14 → U15 transition (OR = 2.26), followed by the U15 → U16 transition (OR = 1.95).

In contrast, and contrary to our initial hypothesis, relative age was not a significant predictor of selection at any transition stage. This finding indicates that relative age did not meaningfully influence selection within transition periods within the present academy system. Furthermore, the small-to-moderate associations observed between MO and relative age support the notion that, although related to some extent, these variables represent distinct developmental constructs. The decreasing magnitude of these associations across age groups further suggests that the relationship between maturity status and relative age becomes weaker as players progress through adolescence.

Our findings indicate that players with more advanced maturity status were more likely to progress to the subsequent age group. Specifically, each one-year increase in MO was associated with approximately twofold greater odds of progression during the U14 → U15 (OR = 2.26) and U15 → U16 (OR = 1.95) transitions. In contrast, MO exerted little influence on selection in the younger age groups, which is consistent with previous research conducted in similar age cohorts (Bidaurrazaga-Letona et al., 2019).

The emergence of maturity-related selection bias during adolescence is consistent with the substantial inter-individual variation in biological maturation that occurs around the onset of puberty (Malina et al., 2019). As maturity-related differences become more pronounced, players with advanced maturity status often exhibit superior anthropometric and physical characteristics compared with their less mature peers (Lloyd et al., 2014). Indeed, players with a more advanced maturity status have been shown to outperform their peers across a range of physical performance measures (Parr et al., 2020). Similarly, players advanced in their maturity status have been reported to achieve greater match-running outputs, including more high-speed distance during competition (Gundersen et al., 2022; Parr et al., 2022). Furthermore, age-group-specific

analyses have demonstrated that players with more advanced maturity status receive greater playing time during official matches, particularly in U13 and U14 age groups (Peñín-Grandes et al., 2025). Collectively, these advantages may shape coaches' perceptions of current and future performance potential, thereby increasing the likelihood that more mature players are retained within talent promotion programmes (Hill, John, McGee, & Cumming, 2023b).

Although our findings align with studies reporting a maturity-related selection bias in academy football (Bidaurrezaga-Letona et al., 2019), the literature remains equivocal. For example, other studies have reported less consistent associations (Deprez, Fransen, Lenoir, Philippaerts, & Vaeyens, 2014; Dugdale et al., 2021b). Notably, Dugdale et al. (2021b) observed that reselected players (i.e., those progressing within the academy system) have been shown to be less mature (lower MO) than their deselected counterparts, while group differences in physical capacities presented higher effect sizes. Therefore, although maturity status may contribute to selection decisions, its influence is likely moderated by additional factors (e.g., technical-tactical attributes) that are also considered within academy environments (Barraclough, Till, Kerr, & Emmonds, 2025; Huijgen et al., 2014).

The maturity-related selection bias observed during the U14→U15 and U15→U16 transitions mirrors the well-documented underrepresentation of players with a less advanced maturity status within youth football academies (Curnyn et al., 2025; Hill et al., 2020a; Johnson et al., 2017). As players progress through adolescence, this bias may progressively reduce the likelihood that later-maturing individuals are retained and promoted within talent promotion programmes (Cumming et al., 2017). Such processes have important long-term implications, as underrepresentation during adolescence has been linked to reduced opportunities for subsequent career progression, including selection to national representative teams (Bonito et al., 2025; Zuber, Zibung, & Conzelmann, 2016).

Importantly, the exclusion of later-maturing players may result in the loss of individuals who possess considerable long-term potential. Evidence indicates that later-maturing players can successfully attain elite performance levels when provided with continued developmental opportunities (Aixa-Requena, Gil-Galve, Legaz-Arrese, Hernández-González, & Reverter-Masia, 2025; Ostojic et al., 2014). This observation aligns with the “underdog hypothesis”, which proposes that competing in physically challenging environments encourages the development of compensatory technical, tactical, and psychological skills that may become advantageous once maturational differences diminish (Cumming et al., 2018; Hill, John, McGee, & Cumming, 2023a). Consequently, deselection during puberty, when factors of biological maturation exerts its greatest influence on anthropometric and physical development through endocrine-mediated processes, including increases in growth hormone and insulin-like growth factor-1 concentrations, may prematurely remove players from the talent pathway before their full developmental potential can be realised (Cumming et al., 2018; Curnyn et al., 2025; Eskandarifard, Nobari, Sogut, Clemente, & Figueiredo, 2022). This concern may be particularly relevant during the U14→U15 transition, which exhibited the strongest maturity-related selection bias in the present study.

Although prior research consistently reports a persistent RAE favouring relatively older athletes in retention and promotion (Brustio et al., 2018; Sweeney et al., 2023), no significant association between relative age and re-selection to the subsequent age group was observed in the present study. Similar findings have been reported in both a Spanish professional academy (U14–U18) (Castillo et al., 2019) and a Scottish academy (U11–U17) (Dugdale et al., 2021b), suggesting that retention decisions within academy environments may be influenced less by relative age than by other performance-related factors. Nevertheless, given the limited number of studies specifically examining the RAE during transition periods, and the tendency of previous research to focus on already selected play-

ers, additional investigations are required to determine whether this pattern is consistent across academy settings.

Importantly, the absence of a significant association between relative age and selection should not be interpreted as evidence for the absence of a RAE within the academy. Relative age-related selection processes may have occurred at earlier stages of talent identification, prior to players entering the academy system. This interpretation is supported by the descriptive data (Table 1), which indicated that the mean birth date across all age groups occurred before the midpoint of the selection year, suggesting an overrepresentation of players born earlier in the year. Such findings are consistent with previous research demonstrating the persistence of the RAE throughout childhood and adolescence in youth football (Hill et al., 2020b; Johnson et al., 2017; Towlson et al., 2022).

These findings suggest that relative age may exert a greater influence during the initial stages of talent identification than during subsequent re-selection decisions within an established academy environment (Hill et al., 2020b; Towlson et al., 2022). However, despite the continued prevalence of the RAE in youth football (Bozděch et al., 2023), the mechanisms underpinning its persistence remain poorly understood. In particular, further research is needed to examine how individual (e.g., birth date), task-related (e.g., playing position), and environmental factors (e.g., social support and coaching practices) interact to influence selection and re-selection decisions throughout the talent development pathway (Hill et al., 2020b; Musch & Grondin, 2001; Wattie, Schorer, & Baker, 2015).

Our findings indicate that relative age did not predict selection decisions, whereas MO emerged as a significant predictor during the later transitions. These results suggest that maturity status and relative age may contribute differently to selection outcomes, despite exhibiting moderate associations during earlier developmental stages. Similar relationships have been reported in European youth football populations (Curnyn et al., 2025; Peñín-Grandes et al., 2025; Sweeney

et al., 2023; Sweeney & Lundberg, 2024; Toselli et al., 2022).

The correlational analyses provide further context for this relationship. Following the U12 and U13 transitions, relative age and MO were moderately associated ($\rho = -0.47$ and $\rho = -0.37$, respectively), which is comparable to the effect size reported by Sweeney et al. (2023), in an Irish U13 national academy cohort ($r = 0.45$). These findings suggest that, during early adolescence, relatively older players may also be more likely to exhibit a more advanced maturity status, resulting in a partial overlap between the two constructs. However, the magnitude of the associations decreased following the U14 and U15 transitions ($\rho = -0.32$ and $\rho = -0.27$, respectively), indicating a weaker relationship between relative age and MO in the older age groups.

Importantly, despite these remaining associations, only MO emerged as a significant predictor of selection during the later transitions. This finding supports the notion that relative age and maturity status represent related but distinct developmental factors and suggests that, as players progress through adolescence, variation in biological maturation may become increasingly relevant to selection decisions compared with relative age (Johnson et al., 2017).

Practical implications

Practitioners working within youth football academies should be aware of the increasing influence of biological maturation on selection decisions as players progress through adolescence. Routine assessments of maturity indicators (e.g., every 3–6 months) help practitioners contextualise performance outcomes and distinguish between attributes that reflect current maturational advantages and those that indicate underlying playing potential (Johnson et al., 2025). In particular, performance in physically oriented assessments and training activities should be interpreted in light of an individual player's maturational characteristics (Ruf, Altmann, Kloss, & Härtel, 2024). Consequently, coach education programmes should include information on the influence of biological maturation

on performance and selection, enabling practitioners to make more informed decisions when evaluating players, particularly those who mature later than their peers.

One potential strategy to address maturity-related selection bias is the incorporation of maturation-informed grouping approaches, such as periodic bio-banding, alongside traditional chronological age-grouping. Although the long-term effects of bio-banding remain to be fully established, current evidence suggests that such approaches may provide later-maturing players with greater opportunities to demonstrate technical, tactical, and psychological competencies, while simultaneously challenging earlier-maturing players to adapt to environments in which physical advantages are reduced (Cumming et al., 2017; Jäger, Rumpf, & Lochmann, 2025).

Finally, academies should consider implementing mechanisms aimed at retaining later-maturing players during adolescence, particularly during periods when maturity-related selection bias appears most pronounced. Examples include extended observation periods or shadow squads (Bennett, Vaeyens, & Fransen, 2018). Such approaches may help reduce the premature deselection of players whose developmental trajectories differ from those of their peers, thereby promoting more inclusive and heterogeneous talent development pathways.

Limitations

While the present study contributes to the growing body of literature examining selection processes in youth academy football, several limitations should be acknowledged. First, although somatic maturity status was estimated using predicted MO, a widely applied non-invasive method, these predictions are prone to estimation error and may be less accurate for individuals who differ substantially from the populations on which the equation was originally developed. Second, the present study focused exclusively on maturity status and relative age and did not account for other factors known to influence selection decisions, such as phys-

ical, psychological, technical, or tactical performance characteristics. Incorporating these variables, as well as their potential interactions with maturity status and relative age, may provide a more comprehensive understanding of player selection processes. Finally, the sample consisted exclusively of male players from a single professional German football academy, which may limit the generalisability of the findings to other academy environments, countries, or female football populations.

Conclusion

The present study demonstrates that player selection during transitions between age categories is susceptible to maturity-related selection bias, particularly during the U14 → U15 and U15 → U16 transitions, where players with higher MO values were more likely to be retained within the academy pathway. In contrast, relative age did not predict re-selection to the subsequent age group. Nevertheless, the observed relative-age skew within the academy sample suggests that relative age-related selection processes may have occurred prior to academy entry.

Furthermore, the association between relative age and MO weakened with increasing age, supporting the notion that these factors represent related but distinct influences on player selection. Practitioners should be aware of the increasing influence of maturity status during adolescence and seek to account for maturational differences when making selection decisions to minimise the risk of overlooking talented later-maturing players.

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Declarations

Conflict of interest. J. Jäger, M.C. Rumpf, R.S. Lloyd, A. Uthoff and M. Lochmann declare that they have no competing interests.

All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 Helsinki declaration and its later amendments or comparable ethical standards. The study sample comprised male football players ($n = 176$) from the U12–U15 age groups of the youth academy of a professional German club whose senior team competed in the 2nd Bundesliga. Players and guardians were informed that anthropometric and additional data would be collected during routine academy assessments, with voluntary participation and the option to withdraw at any time. Written informed consent was obtained from guardians, and assent was provided by the players. Data were anonymized prior to analysis, and retrospective use was approved by the ethics committee of Friedrich-Alexander-University Erlangen-Nuremberg (approval no. 25-207-Sr).

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