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## **Relative Age and Maturation Selection Biases in Academy Football**

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## **Relative Age and Maturation Selection Biases in Academy Football**

This study examined the simultaneous effects of relative age and biological maturity status upon player selection in an English professional soccer academy. 202 players from the U9 to U16 age groups, over an eight-year period (total of 566 observations), had their relative age (birth quarter) and biological maturity (categorised as late, on-time or early maturing based upon the Khamis-Roche method of percentage of predicted adult height at time of observation) recorded. Players born in the first birth quarter of the year (54.8%) were over represented across all age groups. A selection bias towards players advanced in maturity status for chronological age emerged in U12 players and increased with age; 0% of players in the U15 and U16 age group were categorised as late maturing. A clear maturity selection bias for early maturing players was, however, only apparent when the least conservative criterion for estimating maturity status was applied (53.8% early and 1.9% late maturing in the U16 age group). Professional football academies need to recognise relative age and maturation as independent constructs that exist and operate independently. Thus, separate strategies should perhaps be designed to address the respective selection biases, to better identify, retain and develop players.

Keywords: soccer, puberty, talent identification, development, percentage adult height

## 1 **Introduction**

2 The development of talented soccer players is the primary objective of professional  
3 soccer academies and is associated with competitive and financial gains (le Gall,  
4 Carling, Williams, & Reilly, 2010). In England, players can be recruited into  
5 professional academies from eight years of age. Recruited players benefit from  
6 exposure to elite level coaching, sports science and medical support, training  
7 equipment and facilities, and competition (Johnson, Farooq, & Whiteley, 2017;  
8 Meylan, Cronin, Oliver, & Hughes, 2010; Vaeyens et al., 2006). Players who are  
9 initially selected for entry into the academy systems may also have a greater likelihood  
10 of achieving professional status in their sport than those excluded (Cumming, Lloyd,  
11 Oliver, Eisenmann, & Malina, 2017a). The process of identifying those players with  
12 the greatest potential to succeed at the adult level is challenging and necessitates the  
13 consideration of technical, tactical, physical, functional, psychological and cultural  
14 factors (Reilly, Williams, Nevill, & Franks, 2000; Vaeyens et al., 2006).

15 Two non-modifiable factors that have been shown to impact player selection  
16 and performance in academy soccer are relative age and biological maturation  
17 (Meylan et al., 2010; Sierra-Diaz, Gonzalez-Villora, Pastor-Vicedo, & Serra-Olivares,  
18 2017). Relative age refers to a player's chronological age with respect to their  
19 competitive cohort and is determined by date of birth and the competition age-group  
20 cut-off date. A player born at the beginning of the competitive year (September 1<sup>st</sup> in  
21 English soccer) has a relative age advantage of almost one year relative to players born  
22 at the end of the competitive year (31<sup>st</sup> August). Greater relative age is believed to  
23 afford a performance advantage in experience (i.e., more time spent engaged in skill  
24 based activities such as soccer) and greater physical, neural, motor, and/or  
25 psychosocial maturity (Helsen, Hodges, Kel, & Starkes, 2000; Helsen, Van Winckel,

26 & Williams, 2005; Simmons & Paul, 2001; Ward & Williams, 2003; Wattie, Cobley,  
27 & Baker, 2008). Therefore, relatively older players are more likely to be identified as  
28 talented and are, thus, recruited into academies and provided with more support and  
29 investment in their development (Delorme, Boiche, & Raspaud, 2010). The relative  
30 age effect (RAE), whereby a disproportionate number of players are born early within  
31 the competitive year, is well documented in soccer and can be observed in children as  
32 young as six to eight years of age (Helsen, Starkes, & Van Winckel, 1998; Musch &  
33 Grondin, 2001; Sierra-Diaz et al., 2017). The RAE is marked in academy soccer and  
34 appears to remain consistent throughout childhood and adolescence (Barnsley,  
35 Thompson, & Legault, 1992; Baxter-Jones, 1995; Helsen, Van Winckel, & Williams,  
36 2005; Votteler & Höner, 2014). While the RAE can still be observed in adult players,  
37 the magnitude of the bias is often attenuated (Mujika et al., 2009).

38         Biological maturation refers to progress towards the adult state, which varies  
39 with each biological system, and can be viewed in terms of status, timing and tempo  
40 (Malina, Rogol, Cumming, Silva, & Figueiredo, 2015). Maturity status refers to the  
41 specific stage of maturation at the time of observation (e.g., skeletal age, stage of pubic  
42 hair development), while maturity timing refers to the age at which specific  
43 maturational events occur (e.g., age at peak height velocity,). Tempo refers to the rate  
44 at which maturation in a specific system progresses and is more difficult to assess  
45 (Malina, Bouchard, & Bar-Or, 2004). Of relevance to the current discussion, youth of  
46 the same chronological age (CA) can vary considerably in maturity status. Academy  
47 soccer players of the same CA can vary by as much as five to six years in skeletal age  
48 (Johnson, 2015).

49         Individual differences in biological maturity status have been shown to directly  
50 and indirectly influence player performance and selection in youth football (Cumming

51 et al., 2017a). Players advanced in maturity status for their age are more likely to be  
52 selected and recruited into professional academies. Consequently, they are exposed to  
53 greater challenge and gain greater access to superior training facilities and coaching  
54 and sports science/medicine support (Cumming et al., 2017a; Bloom & Sosniak,  
55 1985). The bias emerges about 11 to 12 years and generally coincides with the onset  
56 of puberty (Johnson et al., 2017). The bias is most prevalent in the spine positions  
57 (i.e., central defenders, midfielders, and forwards) and increases with age and  
58 competitive level (Figueiredo, Goncalves, Coelho-e-Silva, & Malina, 2009; Johnson  
59 et al., 2017; Malina et al., 2015; Meylan et al., 2010; Sherar, Baxter-Jones, Faulkner,  
60 & Russell, 2007). Players advanced in maturity status for age are, on average, taller  
61 and heavier than later maturing peers from 9 years on (Cumming et al., 2017a). The  
62 athletic advantages associated with advanced maturation (i.e., greater size, strength,  
63 speed, power) are reasonably well documented among youth soccer players (Meylan  
64 et al., 2010).

65         It is often assumed that players born early in the competitive year benefit from  
66 being physically more mature than their peers. An older CA does not, however, imply  
67 more advanced maturity status. Whereas relative age is a function of birthdate and  
68 competition cut off dates, biological maturity status is largely a result of genetic  
69 inheritance (Malina, 2014). It is entirely possible for a player born early in the  
70 competitive year to be later in maturation and possess little or no advantage in terms  
71 of size and/or athleticism. Conversely, a player born late in the competitive year can  
72 be advanced in maturity status compared to peers and as such experience no  
73 discernible disadvantage. By inference, relative age and maturity status and associated  
74 biases should be considered as independent constructs/processes (Cumming et al.,  
75 2017a). Whereas the RAE is present from early childhood, maturity-related biases do

76 not emerge among youth soccer players until early adolescence and increases with  
77 CA; note, however, the maturity biases are influenced by method of maturity status  
78 assessment (Malina, 2011; Malina, Coelho-e-Silva, & Figueiredo, 2013; Malina et al.,  
79 2015; 2018). A recent study of elite soccer players from two professional academies  
80 showed the RAE was relatively constant from U9 through U17 age groups; however,  
81 selection bias for advanced skeletal maturity status emerged at 11-12 years of age and  
82 increased about 20-fold from U9 to U17 players (Johnson et al., 2017).

83         Whereas relatively older age and advanced maturity status have been shown to  
84 influence performance and selection in academy football, some evidence suggests that  
85 younger and/or later maturing players, if retained within the academy systems, hold  
86 the greatest potential for success as adults (Gibbs, Jarvis and Dufur, 2011; Cumming  
87 et al., 2017a). Referred to as the ‘underdog hypothesis’, this contention holds that  
88 younger and/or later maturing players must possess superior technical/tactical and/or  
89 psychological attributes in order to remain competitive within their cohort (Malina et  
90 al., 2015; Zuber, Zibung and Conzelmann, 2016; Cumming et al., 2018). While this  
91 may not be enough to make them the best player in childhood and adolescence, these  
92 advantages will emerge in late adolescence and young adulthood when age and  
93 maturity-associated variation in size and athleticism are attenuated or, in some case  
94 reversed (Cumming et al., 2018). In support of this contention, later maturing academy  
95 players from England and Switzerland demonstrated superior psychological and  
96 technical/tactical profiles than their early maturing peers (Cumming et al., 2018;  
97 Zuber, Zibung and Conzelmann, 2016). As such, football academies maybe excluding  
98 and/or overlooking players with potential for success in favour of those who are the  
99 most able at the time of assessment (Cumming et al., 2018).

100           The purpose of this study is to examine the simultaneous effects of relative age  
101 and biological maturity status upon player selection in the English professional soccer  
102 academy of Southampton Football Club. The Club has been identified as the most  
103 profitable youth soccer academy in Europe and as an “outstanding example of how  
104 youth training can constitute key competitive advantage both sportingly and  
105 economically” (CIES, 2015). In 2015, fees received by Southampton represented  
106 almost 40% of the total incomes generated by Premier League clubs through the  
107 transfer of club-trained players (CIES, 2015). Southampton’s academy also has an  
108 excellent reputation for effectively nurturing talented yet late developing players  
109 (Lansley, 2016). It was, therefore, of interest to address selection biases within this  
110 prominent and leading academy.

## 111 **Method**

### 112 *Participants*

113 Participants included academy players registered at the Southampton Football Club.  
114 A total of 202 participants spanning U9 through U16 competitive age groups were  
115 assessed once annually, between September and December, over a period of eight  
116 years (2010-2017). Some participants were measured in successive age categories as  
117 they moved through the system. The sample consisted of predominantly European  
118 Caucasians.

### 119 *Ethics and consent*

120 Through the process of registering with Southampton Football Club academy,  
121 individual players and their parents/guardians consent to the routine collection of data  
122 and the potential use of this data for research purposes. All measurements of height  
123 and weight were taken on a voluntary basis and participants had the right not to be



124 assessed. The ethics committee at the University of Bath approved this research study  
125 and the right to use the retrospective data.

### 126 ***Relative age***

127 Relative age was established from the birth date of each player and the cut-off date for  
128 the respective year group (August 31<sup>st</sup>). The selection year for youth football spans  
129 September 1<sup>st</sup> through August 31<sup>st</sup>, and relative age was recorded as birth quarter. As  
130 such, birth quarters were defined as quarter one (oldest-BQ1): players born between  
131 September 1<sup>st</sup> through November 30<sup>th</sup>; birth quarter 2: those born between December  
132 1<sup>st</sup> through to end of February; birth quarter 3: those born from March 1<sup>st</sup> through to  
133 May 31<sup>st</sup>; and finally birth quarter 4 (youngest-BQ4): players born between June 1<sup>st</sup>  
134 through to August 31<sup>st</sup>.

135 To create a more developmentally sensitive measure of relative age, this construct was  
136 also expressed as a decimal, using the difference between player birthdate and the cut-  
137 off date of the selection year, divided by the number of days within the year (Cumming  
138 et al., 2018). Accordingly, relative age is expressed as a value between 0 and 0.99,  
139 with the lowest and highest values representing the youngest and oldest athletes  
140 respectively, for the statistical analysis.

### 141 ***Biological maturity status***

142 Percentage of predicted mature height attained at the time of observation (one  
143 measurement between September and December) was used as the estimate of  
144 biological maturity status (Roche, Tyleshevski, & Rogers, 1983). It is assumed that  
145 among children of the same age, those closer to their predicted adult height are more  
146 advanced in maturation compared to those further removed from predicted adult  
147 height. The Khamis-Roche method (Khamis & Roche, 1994) for the prediction of  
148 adult height was used; the protocol requires current age, height and weight of the

149 youngster and mid-parent height (i.e., mean of the heights of biological parents).  
150 Academy sports science staff using standardized procedures measured height and  
151 weight. Parental heights were self-reported and adjusted for overestimation (Epstein,  
152 Valoski, Kalarchian, & McCurley, 1995). The median error bound between actual and  
153 predicted adult height using the Khamis-Roche method is 2.2 cm in males, from 4 to  
154 17.5 years of age (Khamis & Roche, 1994).

155         Estimated biological maturity status was expressed as a z-score, using the  
156 percentage of adult stature attained at observation and age-specific means and standard  
157 deviations for boys followed longitudinally in the Berkeley Growth Study (Bayer &  
158 Bailey, 1959). The z-scores were used to classify players as late, on-time or early  
159 maturity as in other studies of youth athletes (Cumming, Standage, Gillison, Dompier,  
160 & Malina, 2009; Figueiredo et al., 2009; Gillison, Cumming, Standage, Barnaby, &  
161 Katzmarzyk, 2017; Johnson et al., 2017; Malina, Cumming, Morano, Barron, &  
162 Miller, 2005; Drenowatz et al., 2013). For the primary analysis, a z-score of -1 to +1  
163 defined average maturity status; a z-score greater than +1 defined early status and a z-  
164 score below -1 defined late status. Recognising that the traditional methods for  
165 categorising early and late maturation do not differentiate between individuals who  
166 differ markedly in maturity (e.g., z scores of +.99 and -.99 are both deemed on-time)  
167 and may be less sensitive to subtle biases, a second and less conservative set of criteria  
168 was also considered. For this secondary analysis, a z-score of -0.5 to +0.5 (as currently  
169 employed in the Premier League Player Management Application) was used to define  
170 defined average maturity status; a z-score greater than +0.5 defined early status while  
171 a z-score below -0.5 defined late status (Drenowatz et al., 2013).

172         Classifications of maturity status based on z-scores for percentage of adult  
173 height at the time of observation and differences between skeletal and CA's (SA minus

174 CA) have been compared in American football players 9-14 years (Malina, Dompier,  
175 Powell, Barron, & Moore, 2007) and Portuguese soccer players 11-14 years (Malina,  
176 Coelho-e-Silva, Figueiredo, Carling, & Beunen, 2012). Although the concordance of  
177 classifications was significant and generally moderate, the protocol has demonstrated  
178 concurrent validity in studies of British, North American, and Portuguese youth  
179 (Cumming, Battista, Standage, Ewing, & Malina, 2006; Malina et al., 2012; Rodrigues  
180 et al., 2010; Smart et al., 2012).

### 181 *Statistical methods*

182 The data were analysed using SPSS version 22.0. Descriptive statistics were used to  
183 examine variance in relative age, size, and maturity status across the competitive age  
184 groups. Ordinal regressions with a generalised estimating equation were used to  
185 examine the degree to which relative age and maturity status affected player selection  
186 across age groups (Johnson et al., 2017). An exchangeable correlation structure was  
187 applied to account for correlations among repeated measures of relative age and  
188 maturation within players and improve the estimation efficiency of the models. Odds  
189 ratios and 95% confidence intervals were used to portray the relative likelihood of  
190 group members being present compared to the reference population (under 9 age  
191 group). To assess differences between observed and expected birthdate distributions  
192 (even distribution throughout any 12 month period), a Kolmogorov-Smirnov one-  
193 sample test was used.

### 194 **Results**

195 Descriptive statistics (means and standard deviations) for the variables of interest are  
196 summarized by competitive age group in Table 1. As expected, height, weight, BMI  
197 and percentage of predicted adult stature attained at the time of observation increase,  
198 on average, with CA. Relative age, expressed as a decimal of the selection year, is,

199 on average, above the expected population value 0.5 years in all age groups, and  
200 indicates a greater representation of players born early within a competitive age group.  
201 Estimated maturity status, expressed as z-scores of percentage of predicted adult  
202 height attained at the time of observation, is, on average, negative but approximates  
203 zero among U9 through to U11 players. The mean maturity status z-score is positive  
204 among U12 players and generally increases with CA.

205 \*\*\*\*\*Table 1 near here\*\*\*\*\*

206

207 When expressed by birth quarters (BQ), 54.8% of all players were born in BQ1  
208 of the selection year (September- November); corresponding percentages of players  
209 born in the other birth quarters were 17.3% (BQ2), 15.2% (BQ3) and 12.7% (BQ4).  
210 The RAE is present in every group from U9 through U16 (Figure 1), indicating the  
211 disproportionate number of the youth players in each competitive age group born early  
212 in the selection year (Kolmogorov-Smirnov test,  $D [566]=0.258, p=0.001$ ).

213 \*\*\*\*\*Figure 1 near here\*\*\*\*\*

214

215 Using a z-score of  $\pm 1.0$  for percentage of predicted adult height attained at the  
216 time of observation, the overwhelming majority of the players (84.8%) are classified  
217 as 'on-time' or average in maturity status, while early and late maturing players  
218 comprise 9.5% and 5.7% of the sample, respectively. The relative distributions of late,  
219 on time and early maturing players by competitive age group are shown in Figure 2.  
220 The percentage of early maturing players peaks in the U13 age group at 16.3% and  
221 declines to 5.8% in the U16 group. The percentage of late maturing players peaks at  
222 15.1% in the U9 age group and declines steadily with age. No late maturing players  
223 are represented in the U15 and U16 age groups.

224 Using the less conservative criterion to estimate maturity status (z-score of  
225  $\pm 0.5$  for percentage of predicted adult height attained at the time of observation), the  
226 distributions of players by estimated maturity status within each competitive age group  
227 are shown in Figure 3. With the less conservation criterion, 51.2% of the total sample  
228 is classified as on-time, 30.4% as early and 18.4% as late maturing. By competitive  
229 age groups, the percentage of early maturing players peaks in the U16 age group  
230 (53.8%). With the exception of U9 players, the percentage of early maturing players  
231 increases with CA. In contrast, the percentage of late maturing players peaks at 33.3%  
232 in the U11 age group, and decreases with increasing CA.

233

234 \*\*\*\*Figure 2 near here\*\*\*\*

235 \*\*\*\*Figure 3 near here\*\*\*\*

236 \*\*\*\*Table 2 near here\*\*\*\*

237

238 Results for the ordinal regression analyses are presented in Table 2. The results  
239 indicate a small but significant reduction in the RAE beyond the youngest age group.  
240 Note, however, the magnitude of the differences, though statistically significant, is  
241 small, only a 1% to 2% reduction in likelihood. The magnitude of the differences also  
242 does not vary with CA. The regression results for biological maturity status (z-score  
243  $\pm 1.0$ ) show significant differences in only U13 and U14 players. In these competitive  
244 age groups, advanced maturity status for age is associated with a greater likelihood of  
245 representation compared to the youngest age group. The magnitude of the increments  
246 varies from 3.2 in U13 players to 2.7 in U14 players.

247 When the less conservative maturity criterion is applied (z-score  $\pm 0.5$ )  
248 (Drenowatz et al., 2013), the results for biological maturity status show a significant

249 difference for all competitive age groups from U12 through U16 compared to U9  
250 players. This effect increased in magnitude with each successive age group, ranging  
251 from 2.6 times in U12 to 8.1 times U15 players.

252

## 253 **Discussion**

254 The simultaneous effects of relative age and biological maturity status upon player  
255 selection and retention in a professional soccer academy were evaluated. Consistent  
256 with previous research (Barnsley et al., 1992; Helsen et al., 2005; Musch & Grondin,  
257 2001; Musch & Hay, 1999; Sierra-Diaz et al., 2017), a disproportionate number of  
258 academy players (>72%) were born in the first half of the competitive year. The RAE  
259 was present and greatest among U9 players, and remained relatively consistent across  
260 U10 through U16 players.

261 In contrast, a distinct selection bias favouring players advanced in maturity  
262 status was observed only when a conservative criterion for classification of maturity  
263 status was applied (z-scores of  $\pm 0.5$ ). Using this criterion, the selection bias emerged  
264 in the U12 age group and increased in with age. When the commonly used criterion  
265 for classifying players by maturity status was applied (z-scores of  $\pm 1.0$ ) (Malina et  
266 al., 2005; 2007; Rommers et al., 2019; Cumming et al., 2009), a selection players,  
267 bias favouring players advanced in maturity status was noted only among U13 and  
268 14 players, but the magnitude of the bias was comparatively small. The disparate  
269 findings observed with the two criteria highlight the need for researchers and  
270 practitioners to consider how they define early, on-time and late maturation and the  
271 cut-off points adopted and reinforces the need to imply more sensitive measures of  
272 maturation. The samples used to develop the adult height prediction equations (Fels  
273 Longitudinal Study) and reference values used to convert percentage of predicted

274 adult height into z-scores (Berkeley Growth Study) were developed on children and  
275 adolescents of European ancestry (White) from families of middle and upper  
276 socioeconomic status from, respectively, Ohio (Roche, 1992) and California (Bayer  
277 and Bayley, 1959). In addition, parental heights were reported and not measured.

278         The conservative criterion suggested limited impact of maturity status upon  
279 player selection and retention, while the less conservative criterion suggested  
280 otherwise. Criterion that are too conservative (i.e., z-scores of  $\pm 1.0$ ) may fail to  
281 differentiate between individuals that are markedly different in terms of maturity  
282 status, increasing the likelihood for type two errors. Nevertheless, the range of -1.0  
283 to +1.0 for z-scores to define average status was based upon observations with  
284 skeletal age. The band of  $\pm 1.0$  year approximated standard deviations for skeletal age  
285 within single year CA groups of boys 11-17 years in the general population (Malina,  
286 2011, Malina et al., 2018) and also allows for error associated with estimates of  
287 skeletal age. It should be noted however, that the use of a less conservative criterion  
288 ( $\pm 0.5$  z-score) for determining maturity status may serve as a more sensitive strategy  
289 for detecting biases, it also may increase the likelihood of type one errors. That said,  
290 the increase in the magnitude of the observed bias across the age groups is consistent  
291 with previous research (Johnson et al., 2017), suggesting the presence of such a bias.

292         The results of the current investigation are consistent with studies of youth  
293 soccer players which used skeletal age as the indicator of maturity status, i.e.,  
294 advanced maturity status appeared to act as a positive predictor of persistence,  
295 selection and retention in the sport (Johnson et al., 2017; Malina et al., 2015; Carling,  
296 Le Gall, & Malina, 2012). It should be noted, however, that the majority of the players  
297 in the current investigation, regardless of age group or maturity criterion applied, were  
298 considered 'on-time' with percentage of predicted adult height at the time of

299 observation as the indicator of maturity status. Further, the odd ratios associated with  
300 the maturity selection bias in the current investigation were notably lower than the  
301 equivalent values reported by Johnson et al (2017). Collectively, the findings suggest  
302 that while advanced maturity status is associated with an increased likelihood of  
303 selection and retention in the current cohort, the magnitude of this bias is  
304 comparatively small when considered against other cohorts addressing RAE effects  
305 (Johnson et al., 2017).

306           On the other hand, late maturing players were less likely to be represented with  
307 increasing age, regardless of the criterion employed. This was especially noticeable  
308 in the oldest age groups, with no late maturing players being represented in U15 and  
309 U16 teams. This observation is of particular concern as it in these older groups that  
310 the academies must decide whether to offer players a full-time scholarship or release  
311 them (Mills, Butt, Maynard, & Harwood, 2012). Further research is required to better  
312 understand the nature of this bias and the extent to which talented, yet late maturing  
313 players are being excluded from the academy system.

314           The systematic exclusion of younger and/or later maturing players (Figueiredo  
315 et al., 2009; Johnson et al., 2017; Malina et al., 2015) is of particular concern;  
316 especially as emerging evidence suggest that late maturing players often possess/and  
317 or develop superior technical, tactical, and/or psychological skills. While it has been  
318 argued that the greater physical challenges experienced by the late developers better  
319 prepares them for success as adults, such arguments only hold if these players are  
320 retained within the system. The results from the present study, and previous literature,  
321 suggest that this is not the case (Johnson et al., 2017; Malina et al., 2015). Arguments  
322 that ‘the cream will always flow to the top’ and that relative age and maturity selection  
323 biases are integral parts of what is described as an inefficient, yet effective, model of



324 talent development are flawed in that they fail to recognise that very few younger  
325 and/or late developers are retained in the system. Equally, those who are older and or  
326 advanced in maturity may not be optimally challenged (Cumming et al., 2017a). Such  
327 models are also flawed on the basis that players are selected based on attributes  
328 (relative age, body size and maturity status) over which they have no control and which  
329 are fully realised in young adulthood (Cumming et al., 2017a). Indeed, such models  
330 of talent development are perhaps better described as both inefficient and ineffective;  
331 once late maturing and/or relatively younger players are excluded, they receive less  
332 training, resources and coaching, thus are unlikely to be able to return to the  
333 professional system later (Figueiredo et al., 2009; Musch & Hay, 1999). Reducing  
334 selection biases associated with relative age and biological maturity status whilst  
335 reinforcing meritocracy in football, is an important component of long-term  
336 development of both the players and club.

337         Results of this study provide a unique insight into the selection and retention  
338 practices at a professional soccer academy. Relative age effects were present on entry  
339 into the academy system and persisted through the developmental pathway. In  
340 contrast, the selection bias favouring youth more advanced in biological maturity  
341 emerged among U12 players and increased with age. As small yet inverse relation was  
342 observed between maturity status and relative age ( $r = -0.14$ ,  $p=0.001$ ), indicating that  
343 older players were less advanced in maturation for their age and sex. Although this  
344 finding appears counterintuitive, advanced maturity status may offset some of the  
345 disadvantages associated with being younger (less experience, technical/tactical  
346 aptitude), enabling these players to remain competitive within their age group. More  
347 recently, it was noted that Portuguese soccer players 11 and 13 years of age born late  
348 in the year were tended to be advanced in skeletal maturity for their CA (Figueiredo

349 et al., 2019a). Moreover, birth quarter distributions of Portuguese U13 and U15  
350 players did not differ between those no longer involved and those still competing in  
351 the sport in young adulthood, and also between players playing regionally and  
352 nationally (Figueiredo et al., 2019b).

353           Collectively, the results of the present study support the contention that relative  
354 age, biological maturity status and their respective selection biases operate as  
355 independent constructs/processes and should be considered and treated as such among  
356 youth players. The presence of RAE from mid-to-late childhood suggests that this  
357 phenomenon cannot be attributed to the functional advantages associated with  
358 advanced biological maturation, which emerge with the onset of puberty (i.e., 11-12  
359 years of age). Rather, the RAE in childhood is perhaps more likely to reflect age-  
360 related variation in a variety of other factors including neuromuscular maturation,  
361 behavioural development, experience, training, and perhaps other factors. The  
362 evidence would also suggest that strategies designed to address the RAE should focus  
363 on such attributes and be introduced from early childhood; whereas strategies to  
364 address individual differences in biological maturity would be most effective during  
365 early and mid-adolescence. Though potentially interesting, what is lacking in research  
366 interpreting the RAE and variation in biological maturation is the interactions between  
367 these variables and the adults who train and select youth players, which may perhaps  
368 be labelled the “environment of the academy”.

369           Several strategies have been advanced to address RAE and maturity-related  
370 selection biases in sport. Use of age-ordered shirt numbers, for example, reduced the  
371 selection bias associated with relative age among professional scouts (Mann & van  
372 Ginneken, 2017). In a similar vein, a number of professional academies have  
373 experimented with ‘quarter four trial days’, whereby only players born in the fourth

374 quarter of the competitive year are allowed to participate (Hibernian Media, 2016). An  
375 “average team age rule”, whereby teams may consist of players with a mean within a  
376 specific range, has also been advanced as potential solution to the RAE (Andronikos,  
377 Elumaro, Westbury, & Martindale, 2016; Lawrence, n.d.).

378         In an effort to balance maturity-related variation, the Premier League recently  
379 trialled the practice of bio-banding whereby players within a specific CA range are  
380 grouped by estimated maturity status. As a practice, bio-banding is designed to  
381 attenuate and better manage maturity-associated differences in size and function and  
382 to expose early and late maturing players to novel and more developmentally  
383 appropriate learning experiences (Cumming et al., 2017a). Players have unanimously  
384 supported bio-banding (as an adjunct to age group competitions), though reasons for  
385 doing so varied with maturity status (Cumming et al., 2017b). Playing up, early  
386 maturing, chronologically younger boys described their experiences as more  
387 physically and technically challenging, as a better learning experience, and as an  
388 opportunity to play with and be mentored by chronologically older yet physically  
389 matched peers. Such opportunities may also help early maturing boys develop the  
390 same psychological and technical/tactical qualities that appear requisite for the  
391 survival of the late maturing players (Cumming et al., 2018; Zuber, Zibung and  
392 Conzelmann, 2016). Late maturing, chronologically older players described their  
393 experiences as less physically and technically challenging, but appreciated the  
394 opportunity to use/demonstrate their physical and technical attributes, and to adopt  
395 positions of leadership (Cumming et al., 2017b). Although results of the Premier  
396 League bio-banding initiative are promising, further research applying and evaluating  
397 the strategy is required.

398           Several limitations of the current study should be noted. First, the results are  
399 specific to a single football academy and may not be generalizable to other clubs,  
400 competitive programmes, or countries. Second, the method used to estimate biological  
401 maturity status used self-reported adult heights and the height prediction equation and  
402 reference values used to derive the z-scores were based on samples of European  
403 (White) ancestry in the United States (Ohio and California). Moreover, percentage of  
404 predicted adult height at the time of observation may not be directly comparable to  
405 studies using more clinically based estimates of biological maturity status, specifically  
406 skeletal age or stage of pubertal development (Malina et al., 2004). Spearman rank  
407 order correlations between the protocol used in the present study and skeletal age and  
408 stage of pubic hair development, though moderate, were higher in soccer players 13-  
409 14 years compared to players 11-12 years (Malina et al., 2012).

410           In summary, selection biases towards players who are born earlier in the  
411 competitive year and who are advanced in biological maturation exist in academy  
412 football. Relative age effects were present from entry into the academy system and  
413 maintained throughout the competitive age range considered, while biological  
414 maturity status selection biases were only evident from early adolescence when the  
415 less conservative criterion for estimating maturity status was applied. The results were  
416 also consistent with the contention RAE and maturity status related selection biases  
417 are separate processes and as such should be considered independently. Further  
418 research is required to better understand the nature and sources of the selection biases  
419 and how they may be used to optimise opportunity for all youth players.

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