Skeletal maturation status is more strongly associated with academy selection than birth quarter

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ABSTRACT

Introduction: Selection of younger athletes for advanced training in elite sport is assumed to be based on identification of innate talent. Previous researchers have identified relative age effects to influence these selection processes; however, maturation status and skeletal age effects, which have the potential to be a greater influence, have not been widely examined.

Methods: Skeletal age (categorising athletes as: early maturing, on time, or late maturing via wrist and hand X-ray and Fels classification) and birth quarter are documented for 472 boys from Elite Youth football academies and compared to reference normative data to assess their effect on academy selection. **Results**: It is seen that maturation status has a much stronger influence – approximately 10-fold – on selection with a systematic over-representation of early maturing athletes in elite football academies, an effect that increases with age.

Conclusions: Our results demonstrate that athletes are being chosen in large by their maturation status, and as this relative benefit will have disappeared once all athletes are skeletally mature, this process is inadvertently excluding the majority of potential candidate athletes from this selection process. We suggest that consideration of maturation status of candidate athletes will result in a more equitable exposure to advanced training and the resultant performance benefits this incur.

Introduction

Elite sport is a significant financial and social aspect of the lives of many people. Professional soccer or football, as it is more commonly termed in Europe, is said to be the most popular sport worldwide, with the greatest number of participants and spectators, and consequently has an important impact in many areas. In professional football, players can be identified by professional club scouts as young as 8 years of age, but the criteria used to select these players are not well validated. It is known, however, that once selected in high-level professional academies, players are much more likely to reach the ranks of senior professional play, whereas those excluded are not (Figueiredo et al. 2009). Underlying such decisions to choose individuals is a premise that innate talent or ability is able to be identified and then subsequently nurtured during the youth academy period to allow the creation of the most successful senior team. The identification and subsequent development of the most talented players is therefore an important topic for investigation.

Success in elite sport is thought to be reliant on the initial identification and subsequent development of the most highly talented athletes in that environment. To become an expert practitioner, a significant amount of deliberate practice is required (Ericsson & Lehmann 1996). Within the industry, historically successful organisations are thought to have high-quality coaching which is provided to develop these talented athletes (Goncalves et al. 2012); however, this limited resource can only be delivered to a fixed number of potential athletes. Maximising the exposure of these high-quality coaching staff to the most skilled junior players is an important strategy to optimise success. To this end, significant resources are placed in the identification of the most "talented" junior players who will then be subjected to more intensive targeted training, at the expense of the less talented others who are excluded from these systems.

Anthropometric differences (height and mass) of players, particularly in the younger age groups, have been identified as playing an important role in performance and selection with physically bigger players chosen over the smaller players. Having a birth date immediately after the classification cut-off for age-based junior sport provides a developmental advantage over those born immediately before this date up to one year. These "relative age effect" (RAE) advantages in development are seen to be enough to improve selection likelihood for youth athletes which carry through to adult-level elite sport where such early age-related advantages in development will have disappeared (Helsen et al. 2000, 2005; Simmons & Paull 2001; Vaeyens et al. 2005; Wattie et al. 2008; Hirose 2009). This has been termed the "initial performance effect" (Helsen et al. 2005; Jimenez & Pain 2008), and providing such an advantage to those lucky enough to have been born at the right time may be excluding others from exposure to training who may have sufficient skill, yet lack the physical development of their more mature colleagues. Indeed, studies from both French and Spanish football suggest that the RAE is a contributor to drop out rates in junior, but not adult football (where relative age effects of physical maturation will no longer exist) (Jimenez & Pain 2008; Delorme et al. 2010). At the highest level, boys who have been lost to the football academy system are unlikely to be later identified as potential senior players in the professional ranks (Figueiredo et al. 2009).

While the initial performance effect benefit of the RAE is now well documented, the magnitude of this effect can at most be one year for each age banding. An unexplored, but potentially even greater effect could be seen through individual variation of biological maturity. At the extremes, this variation has been documented to be up to 6 years difference (for two 9-year-old boys (Johnson et al. 2009)). Skeletal age maturation is non-linear and varies between individuals, genders, and races (Malina 1969, 1970). Biological maturity status is estimated using a variety of methods, invasive and non-invasive, which document the extent of an individual's maturation referenced against normative population data in comparison with their chronological age. Skeletal age maturation which is assessed most frequently using a plain X-ray of the wrist and hand is said to be the gold standard for the estimation of maturity status (Malina et al. 2004; Engebretsen et al. 2010). The interaction between the RAE and biological maturity has been examined in only a limited number of studies. Indirect measures of skeletal maturation status such as peak height velocity (Mirwald et al. 2002; Deprez et al. 2013) (PHV) as described by Mirwald (Mirwald et al. 2002) have been used as non-invasive measures of biological age in several studies involving youth football players (Philippaerts et al. 2006; Deprez et al. 2013; Gil et al. 2014), but the study by Hirose (Hirose 2009) is the only study to our knowledge which used a plain X-ray of the wrist and hand and related this to the birth period. This group examined 334 players of Japanese origin in the under 10 to under 15 age bands confirming the RAE as well as a bias selection for players of slightly higher skeletal age in the bands under 12 to under 15 inclusive (but not under 10 and 11). It would be worthwhile to examine older players who are closer to entry in the senior (adult) academies and see whether these effects remain.

We hypothesise that since academy selection appears to be biased towards physically larger and chronologically older athletes, an effect of skeletal age will be seen in academy selection. Accordingly, the aim of this study was to document the existence of any biological age effect on academy selection while controlling for the RAE.

Methods

Skeletal age and maturation status

A total of 293 academy participants from an English Premier League football academy (Manchester United) and 179 participants from a Middle Eastern Sports academy (Aspire) had their skeletal age determined annually over a period of 6 and 4 years, respectively, for a total of 1115 observations. All birth dates were extracted from the participant's medical records.

Skeletal age measurements were taken by a single examiner (with previously demonstrated inter-tester ICC reliability of 0.998) as part of the routine annual medical screening (Johnson et al. 2009). As part of this medical screening, a plain anteroposterior X-ray of the left hand and wrist was taken. The Fels method was used to estimate skeletal age from this film (Roche et al. 1988). The players were categorised as early maturers if their skeletal age was greater than 1 year above their chronological age, normal maturers if they were within 1 year of their chronological age, and late maturers if they were more than 1 year below than their chronological age (Malina et al. 2004).

Relative age effect (birth quarter)

Birth quarters were dictated by the respective entry dates for the football leagues in the respective countries. Accordingly, for the boys from the English (Manchester United) academy, birth quarters were defined as quarter one: players born from September until the end of November; quarter 2: players born from December until the end of February; quarter 3: players born from March until the end of May; and quarter 4: players born from June to the end of August.

For the Middle Eastern (Aspire) academy, the birth quarters were defined as quarter 1: players born from January until the end of March; quarter 2: players born from April until the end of June; quarter 3: players born from July until the end of September; and quarter 4: players born from October until the end of December.

Ethics and informed consent

Individual footballers as well as their parents/guardians were given information and allowed to ask questions regarding the screening of biological age. Signed consent for the screening was sought and obtained prior to any examination. Participation in the screening was voluntary, and assurances were given that their status in the academy would not be affected if they did not wish to undergo any aspects of the screening process.

This research was approved by the Qatar Anti-Doping Lab Ethics Committee and the Manchester University Ethics Committee.

Statistical methods

All data were coded and analysed in SPSS version 21.0 (IBM Corp. Armonk, NY). To assess the independence of birth quarter or Fels skeletal age classification with age group, chi-square test was performed. To determine the association of birth quarter with age group, an ordinal regression using generalised estimating equation was performed using exchangeable correlation structure to account for the repeated selection of some footballers in the subsequent seasons. To compare skeletal age with a reference ("normal") population, the skeletal ages of the academy participants were compared with the original reference data of the population described by Roche et al (Roche 1980), which forms the basis of the Fels classification system. Briefly, this reference population comes from a longitudinal study conducted over more than 45 years in the United States, which established the distribution of skeletal markers (hand and wrist maturation) and their distributions relative to true "chronological" age from birth until 18 years of age. Post hoc adjustment for multiple comparisons was made with Bonferroni adjustment, with P = 0.05 set a priori as denoting statistical significance. Odds ratios (and 95% confidence intervals) are presented depicting relative likelihood of group members being present compared to relevant reference populations. Between-group differences are presented as effect sizes (Cohen's d) classified as small (d = 0.2), medium (d = 0.5), and large (d ≥ 0.8) (Cohen 1988).

Results

The results of the statistical analyses are presented in Tables 1, 2, 3, and 4 and Figures 1, 2, and 3.

Players born in the first and second quarters were over-represented across all age groups (U-9 to U-16), except under 17 where the RAE was not observed (P = 0.704, Figure 1). On the other hand, the skeletal age effect showed significant differences from the age category of U12 onwards compared to U9 (Tables 1, 2, and 3; Figure 2). This effect increased in magnitude with each successive age category (OR = 2.2, 95% CI (1.3 to 3.8) for the U-12 category and OR = 20.0, 95% CI (8.3 to 47.8) for U-17 (Table 1, Figure 2)).

Discussion

These data clearly show that as these players age, they are selected for these elite academies from a biased sample of early maturing boys and that this effect became more pronounced the older the boys became, to a maximum of a 20-fold increase in likelihood. Birth quarter effect was seen; however, its magnitude was not as great across the cohort with a peak of 2.2 times more likely for those with a positive RAE. These academies are seen to be favouring selection of boys born earlier in the selection year to a relatively small degree, but to a much larger extent they are favouring earlier maturing athletes. This disadvantage for the later maturing athletes is most pronounced in the later academy years, as the boys move closer to adult participation. Speculatively, the early maturing athletes may have a physical (e.g., strength) advantage over later maturing boys which could explain their selection bias in the academies; however, the association between maturation status and physical strength has not been well documented, so this remains an area for future investigation.

For a young player to gain success in professional football, there are a number of hurdles which need to be negotiated. Variables such as training load, intensity, and compliance can be manipulated, but other variables such as date of birth and maturity status are fixed. The data presented here show that the influence of these two factors in determining the success rate of young players could be critical in the selection and retention process of young players, but these are often disregarded.

The discrimination against the relatively (skeletally) younger and likely smaller players means these players are unlikely to be offered the same opportunities in the selection process and are more likely to drop out of a programme or are unable to rejoin a professional programme at a later date (Musch & Hay 1999; Delorme et al. 2010). The net effect of this exclusion of these less physically developed boys is a shrinking of the available pool of players to draw from. If the most skilled adult players are evenly dispersed across the entire population, irrespective of adolescent maturation status, then drawing the majority of the academy players from the biased sample of early maturers is a flawed strategy – in essence the pool to select talent from has been greatly reduced by excluding late and normal maturers. Indirect evidence suggests that later maturing adolescents are more likely to achieve adult success. A cohort of 55 14-year-old boys followed prospectively for 8 years showed that the late maturing players were at a higher chance of achieving the highest professional status in professional football (Ostojic et al. 2014). Similarly, later born players have been demonstrated to earn more than their younger peers in elite German football

Table 1. Ordinal regression with age group and birth period category and skeletal age classification.

	Birth period		Skeletal age	
Team	OR (95% CI)	*P* value	OR (95% CI)	*P* value
U-9	1.0		1.0	
U-10	1.1 (0.9 to 1.2)	0.268	1.1 (0.7 to 1.7)	0.784
U-11	1.0 (0.8 to 1.3)	0.874	1.6 (0.9 to 2.7)	0.092
U-12	1.0 (0.8 to 1.4)	0.773	2.2 (1.3 to 3.8)	0.006
U-13	1.1 (0.8 to 1.6)	0.453	2.4 (1.4 to 4.2)	0.001
U-14	1.1 (0.8 to 1.5)	0.718	3.5 (1.8 to 6.7)	<0.001
U-15	1.2 (0.8 to 1.7)	0.432	4.9 (2.4 to 10.1)	<0.001
U-16	1.1 (0.7 to 1.7)	0.567	10.4 (4.9 to 22.1)	<0.001
U-17	2.4 (1.5 to 3.8)	0.000	20.0 (8.3 to 47.8)	<0.001

Table 2. Estimated marginal means of skeletal age z-score (Fels classification) by age group and academy. Significant differences are noted where present (P < 0.05, Bonferroni adjustment for multiple comparisons employed). The estimated marginal means describe the z-score of the academy cohort in comparison with reference data. For example, −0.2 ± 1.1 denotes an average z-score of 0.2 lower than the reference Fels classification age group with a standard error of 1.1 (z-units). N denotes the number of participants in the particular group.

	Manchester United Academy			Aspire Academy			Manchester United compared to Aspire Academy t-test
	N	Mean±SE	Sig. Diff	N	Mean±SE	Sig. Diff	*P* value
U-9	128	−0.2 ± 1.1	U-12,U-14, U-15, U-16				
U-10	117	−0.2 ± 1.1	U-12, U13, U14, U15, U16				
U-11	89	0.0 ± 1.2	U-12,U-14, U-15, U-16				
U-12	100	0.3 ± 1.1	U-9, U-10, U-10, U-15, U-16	7	0.6 ± 1.7		0.198
U-13	88	0.2 ± 1.3	U-10,U-15, U-16	54	0.6 ± 1.0	U-15, U-16, U-17	0.004
U-14	74	0.5 ± 1.2	U-9, U-10, U-11,U-15,U-16	62	0.8 ± 1.0	U-16	0.004
U-15	60	1.1 ± 1.3	U-9, U-10, U-11, U-12, U-13, U-14	96	1.0 ± 1.2	U-13,U-16	0.265
U-16	62	1.2 ± 1.0	U-9, U-10, U-11, U-12, U-13, U-14	61	1.3 ± 1.2	U-13, U-14, U-15	0.008
U-17				59	1.2 ± 1.0	U-13	

Table 3. Comparison of skeletal age group classification with reference population (Roche et al).

Reference population				Academy population					
N	Mean	Variance	SD	N	Mean	SD	*P* value	Cohen's d	Effect size descriptor for the difference
394	9.1	1.1	1.0	117	9.6	1.2	<0.001	0.360	Small to medium
319	10.1	1.1	1.0	89	10.8	1.3	<0.001	0.530	Medium to large
303	11.2	1.3	1.1	107	12.1	1.2	<0.001	0.726	Medium to large
291	12.2	1.4	1.2	142	13.0	1.2	<0.001	0.617	Medium to large
280	13.3	1.1	1.1	136	14.3	1.2	<0.001	0.894	Large to very large
275	14.2	0.9	1.0	156	15.5	1.3	<0.001	1.119	Large to very large
263	15.2	1.2	1.1	123	16.8	1.1	<0.001	1.375	Large to very large
242	16.3	1.4	1.2	59	17.3	0.9	<0.001	0.686	Medium to large
222	17.3	1.1	1.0	57	17.7	0.5	0.003	0.362	Small to medium

Table 4. Maturation status for the two academies, described by playing age group with total number of boys and percentages for the individual age group and individual academy in parentheses. Note that Manchester United Academy accepts boys from the under-9 age group (U9) up to under-16, whereas Aspire academy accepts boys starting at Under-12 until they graduate high school at under-17.

		Age group category								
		U9	U10	U11	U12	U13	U14	U15	U16	U17
Manchester United Academy	Early	18 (14%)	17 (15%)	23 (26%)	29 (29%)	26 (30%)	23 (31%)	32 (53%)	39 (63%)	
	Normal	83 (65%)	79 (68%)	52 (58%)	60 (60%)	51 (58%)	43 (58%)	24 (40%)	22 (35%)	
	Late	27 (21%)	21 (18%)	14 (16%)	11 (11%)	11 (13%)	8 (11%)	4 (7%)	1 (2%)	
	Total	128 (100%)	117 (100%)	89 (100%)	100 (100%)	88 (100%)	74 (100%)	60 (100%)	62 (100%)	
Aspire Academy	Early				8 (26%)	61 (42%)	105 (54%)	103 (54%)	141 (70%)	129 (74%)
	Normal				18 (58%)	78 (54%)	83 (43%)	82 (43%)	52 (26%)	35 (20%)
	Late				5 (16%)	6 (4%)	6 (3%)	4 (2%)	8 (4%)	11 (6%)
	Total				31 (100%)	145 (100%)	194 (100%)	189 (100%)	201 (100%)	175 (100%)

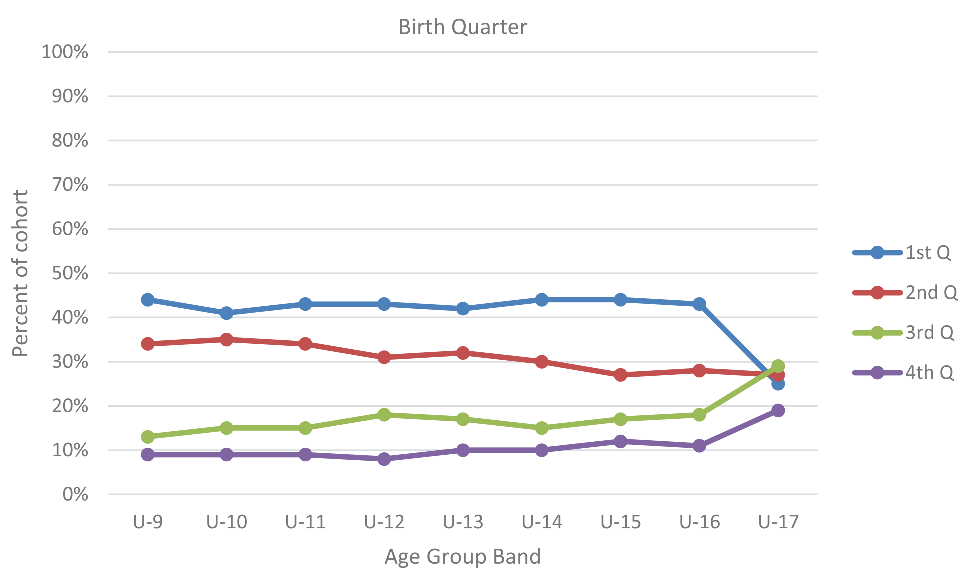

Figure 1. Birth quarter for the individual age group bands for the entire cohort.

(Ashworth & Heyndels 2007) and be chosen earlier in the draft for the National Hockey League in the United States (Baker & Logan 2007). Indeed, a relatively recent examination of Ice Hockey data suggests that younger born players have longer professional careers – an indirect measure of player skill (Gibbs et al. 2011)

Previous work has looked at the birth month distribution and physical body size of adolescents (Malina et al. 2007; Carling et al. 2009) and demonstrated that players who mature earlier are favoured for selection. It is unknown whether this is due to the maturation status of these players or attributable to these players simply being physically larger. A player who has a maturation status advantage will only have a physical advantage until all players reach skeletal maturity where these effects will disappear; however, if players are being excluded from exposure to higher-level practice and training in academies, they are unlikely to achieve the same ultimate playing status.

These data have shown that while the relative age effect is present in this cohort, its magnitude is much smaller in comparison with the ramifications of skeletal age maturation status. The magnitude of this effect is seen to vary with age

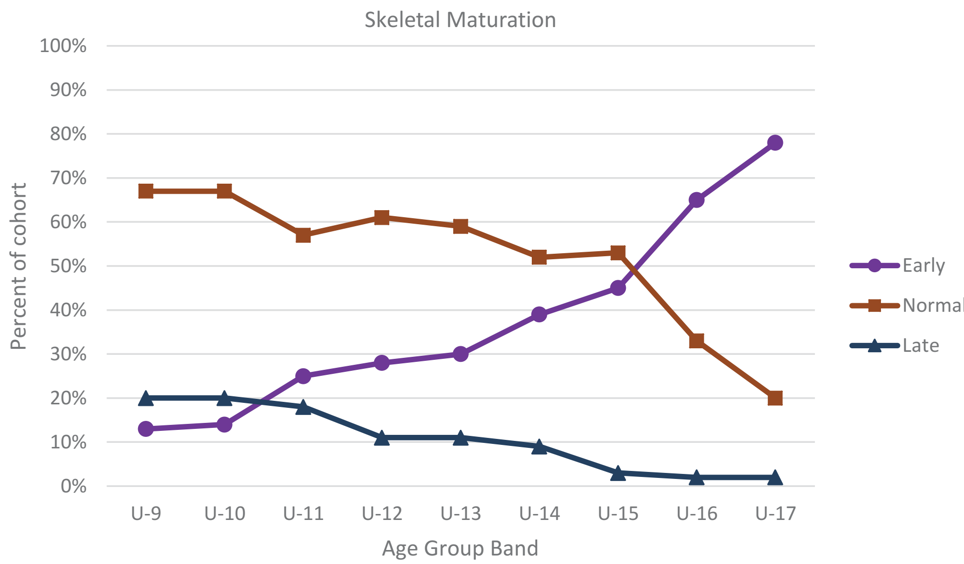

Figure 2. Skeletal maturation status for the entire cohort. Note the increasing prevalence of early maturing athletes as age increases at the expense of normal and late maturing athletes.

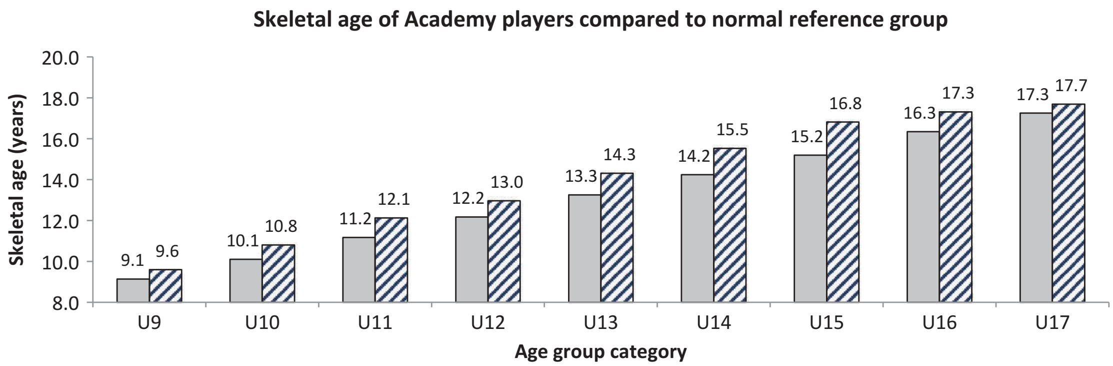

Figure 3. Average skeletal age of academy athletes (diagonal hatch) compared to reference population (grey bars) showing academy athletes to have a higher average skeletal age at every age group category.

group participation, intensifying as the age of the participants increases, whereas the birth quarter effect seems to remain relatively constant. There were no differences observed between the European and Middle Eastern cohorts in terms of relative age effect; however, skeletal age maturation status showed differences at some ages. Superficially, this would suggest that late maturers, with late birthdays, are given fewer opportunities than physically larger and biologically more mature players are given. This results in a systematic underrepresentation of late maturers, a finding which concurs with other research in the area (Hirose 2009). More careful observation of Figure 2 shows that early maturers become increasingly over-represented with increasing age; however, Figure 4 shows that there is no birth quarter effect seen in this subgroup. These data underscore our contention that irrespective of the perceptions surrounding selection influences and procedures in football academies ("talent", "skill", and "development prospect") and despite increasing knowledge of the birth quarter effect, skeletal maturation status is much more strongly associated with selection.

We suspect that the much stronger effect seen by skeletal age maturation status can be explained by the notion that birth quarter can account for, at most, 1 year difference in chronological age; however, variation in skeletal age (for the same chronological age group) can be as much as 6 years (Johnson et al. 2009), and in this cohort, it is seen to be, on average, 0.91 years (Figure 3).

Selection procedures are said to be based on perceived football ability; however, these data suggest that this process is unwittingly being strongly influenced by skeletal age status. It has been suggested that the tendency to choose a physically more developed youngster is the desire for immediate success for the team rather than long-term development of a player (Augste & Lames 2011). If there is a real effect of "ability" that is independent of RAE and biological status, then it appears that academies could improve their pool of available talent to draw from by widening their net to those who are on time or late maturers. This is an important finding as these boys can be expected to all fully skeletally mature within the following few years after leaving the academy where these relative difference

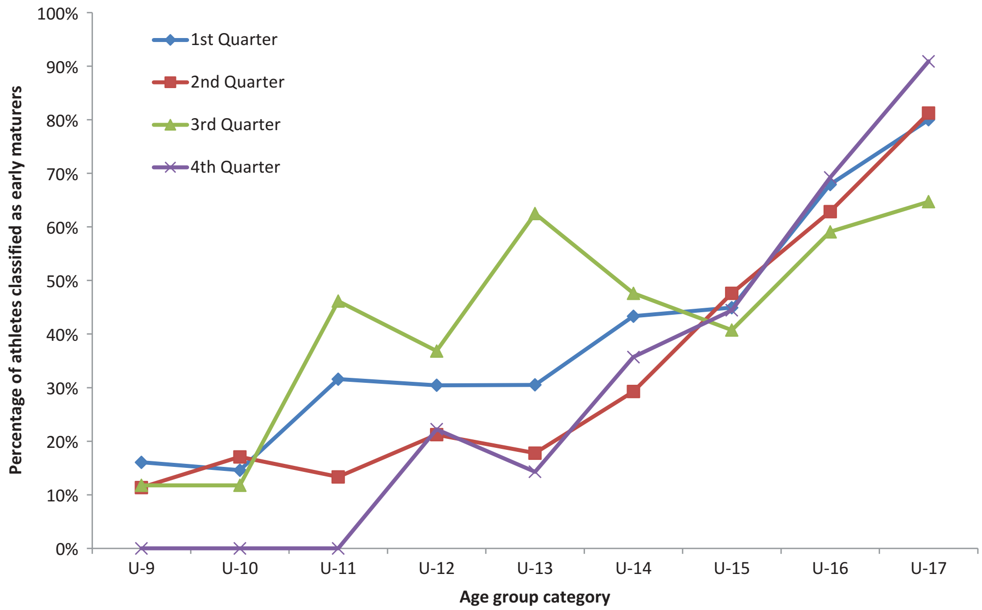

Figure 4. Prevalence of academy athletes classified as early maturers in each age group category classification when considered by birth quarter showing a clear increase in proportion of early maturing athletes with no clear effect of birth quarter.

effects will pass; however, those boys lost to the system will be unlikely to be afforded an opportunity to rejoin. We suggest that including an estimation of skeletal age using a valid and reliable method and considering this information in the selection and retention policies will ultimately result in better performance outcomes. Future research could address the reasons coaches preferentially select these early maturing players which likely include, but are not limited to body size and physical fitness and the interaction with "talent" and "skill". Understanding and including these biases could result in improved practice. For both these boys who are discriminated against by this process and the organisations who hope to have the most talented pool of players to draw from available, this approach would appear to be worthy of reappraisal with these data in mind.

Conclusion

This work has documented that skeletal age is a stronger factor influencing decisions in football academies, independent of the relative age effect. The magnitude of the effect for skeletal age is seen to increase with age and is markedly stronger than the birth quarter effect.

The current system of age banding is detrimental to the chances of academy selection for both those born in the later quarters of the year and especially to those who skeletally mature later. Reappraisal of this system with these biases in mind could result in choosing academy players more equitably from a larger pool. We suggest that since the effect of skeletal age will be essentially zero after skeletal maturation has occurred (at approximately 18 years of age), academy selection processes are inadvertently disadvantaging their ability to produce the maximum number of quality adult players by preferentially selecting players from the subset of athletes who are skeletally more mature than average.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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