Coaches' eye as a valid method to assess biological maturation in youth elite soccer

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Abstract: Consideration of maturity is recommended in the talent identification and development process. Skeletal age (SA), prediction of age of peak height velocity (APHV) and an estimation of biological maturation by coaches' eye of 121 soccer players were compared. The SA of soccer players was 13.9 ± 1.1 years, and did not differ significantly from chronological age (CA). Agreement between the SA-CA classifications and APHV was 65.5%. Spearman rank-order correlation (r_s) between maturity classifications was moderate, kappa (k) was 0.25. Agreement between SA-CA classifications and coaches' eye was 73.9%. The r_s between maturity classifications was strong, k was 0.48, which was better than the widely used APHV assessment. Therefore, estimations of experienced coaches seem to be an acceptable alternative method for classifying maturity in youth athletes.

Keywords:
skeletal age, age at peak height velocity, coach estimation, maturation, young athletes

Introduction

Talent identification (TID) in soccer is a necessary process in talent development (TD) programs, but it requires a considerable understanding of the game demands as well as knowledge of human growth and maturation. Game performance depends on multiple factors, including physical, technical, tactical, mental and physiological elements (Williams & Reilly, 2000). Many of these factors, including height, speed, endurance and cognition, are highly dependent on biological age (BA) (Malina, Bouchard, & Bar-Or, 2004; Malina, Coelho e Silva, & Figueiredo, 2012). Therefore, elite youth athletes in a variety of sports such as soccer and ice hockey tend to have advanced biological maturity during late childhood and adolescence (Malina et al., 2012; Unnithan, White, Georgiou, Iga, & Drust, 2012; Vaeyens, Lenoir, Williams, & Philippaerts, 2008). Grouping by chronological age (CA) is the customary procedure for separating young players into age-related training and competition groups. However, the biological age (BA) of individuals in the same age category can vary by as much as four years (Malina et al., 2004). In boys, this trend is mostly observed between 13 and 16 years of age when the differences in maturity status are amplified by the timing and tempo of adolescent growth spurts (Figueiredo, Goncalves, Coelho e Silva, & Malina, 2009a; Hirose, 2009). Therefore, maturity may play a crucial role in the coaches' view of an athlete's potential and the chance of a young player achieving senior elite status. Specifically, data for soccer suggests that a disproportionately large number of late maturing players are excluded, and coaches favour average and early maturing players (Figueiredo et al., 2009a). Till et al. (2014) showed that the process of favourably selecting relatively older and early-maturing athletes within competitive youth sports may be counterproductive in the long-term. The current process may exclude skilled individuals from attaining the elite level due to their delayed maturity in comparison to early maturing peers. Consequently, maturation characteristics should be considered in any TID and TD program to provide fair selection and to invest available resources appropriately (Unnithan et al., 2012; Vaeyens et al., 2008). For example, the widely-used long-term athlete development

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model recommends the identification of early, on-time and late maturation stages (Balyi & Hamilton, 2004). Therefore, the biological maturity assessment of youth athletes is an important aspect of TID in soccer as well as in other sports.

Amongst different methods, skeletal age (SA) is said to be the best indicator of BA, and could be a more meaningful way to evaluate the performance of young athletes than CA (Malina et al., 2004; Tanner, Healy, Goldstein, & Cameron, 2001). The classical method for assessing SA is based on the comparison of actual bone characteristics and maturity indicators of hand-wrist X-rays using reference images from Greulich and Pyle (Greulich & Pyle, 1959), Tanner et al. (2001) or the FELS method (Roche, Chumlea, & Thissen, 1988).

However, SA assessments are associated with practical and ethical problems (radiation exposure to healthy children and adolescents), high costs (medical staff, material) and specific expertise for evaluation (Sherar, Cumming, Eisenmann, Baxter-Jones, & Malina, 2010). Exposure to radiation is the main problem with using conventional X-rays in TID (Hall, 2009). In modern technology, the assessment of SA by hand-wrist requires less than 1 μSv of radiation via conventional radiography (Mettler Jr, Huda, Yoshizumi, & Mahesh, 2008; Romann & Fuchslocher, 2016); 1 μSv of radiation is the equivalent of less than four hours of natural background radiation or 10 minutes on an intercontinental flight (Mettler Jr et al., 2008). Nevertheless, to avoid the possible detrimental effects of cumulative radiation exposure, children and adolescents should only be exposed to a minimal amount of radiation (Hall, 2009; Radiological Society of North America, 2017). Consequently, avoiding any radiation when assessing maturation is an important issue, and methods involving less radiation or none at all are preferable, particularly in childhood and adolescence.

Secondary sex characteristics and somatic measurements are the most common methods used to categorise maturity that do not use radiation (Mirwald, 2002; Tanner et al., 2001). The indicators considered when assessing maturity status by secondary sex characteristics are generally the development of breasts (in girls), genitals (in boys) and pubic hair (boys and girls). The rating of secondary sex characteristics as a measure of maturity status is only useful during puberty; hence, it does not cover the full spectrum of growth. The protocols are often viewed as an invasion of personal privacy. In addition, the validity of the results, financial resources and access to a physician may be factors that limit the use of this method in a practical setting (Malina, Coelho, Figueiredo, Carling, & Beunen, 2012).

A common maturity-assessment technique used in the literature is the determination of years based on peak height velocity (PHV). PHV is an indicator of somatic maturity, and it reflects the age at the maximum growth rate in stature during adolescence (age of PHV [APHV]). Mirwald et al. (2002) developed an equation using regression analysis to predict APHV, and they reported that APHV could be predicted ±1 year. Current height, weight, age, sitting height, estimated leg length (height minus sitting height) and interaction terms are used to estimate the time before or after PHV, and, in turn, to predict APHV (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). This approach has also been found to have good reproducibility and good agreement with maturity status as calculated from hand-wrist X-rays (Matsudo & Matsudo, 1994; Mirwald, 2002). However, Malina et al. (2012) have demonstrated that a relatively poor correlation exists between maturity status calculated via the FELS method and Mirwald's equation, and they suggested that Mirwald's equation was not sensitive enough to classify players into maturity groups in comparison to X-ray results.

Therefore, more practicable and valid methods are warranted. Many soccer clubs and soccer federations select their players using the subjective assessments of scouts and coaches (Reilly, Williams, Nevill, & Franks, 2000). The scout or coach-driven TID methods are based on multifactorial intuitive knowledge, which includes socially-constructed images of the perfect player. Generally judgements can be categorised as either intuitive or deliberate (Kruglanski & Gigerenzer, 2011). Deliberative judgments have been assumed to be analytical, rational, rule-based, conscious, and slow. Intuitive judgments have been assumed to be associative, unconscious, heuristic, error-prone and quick (Kruglanski & Gigerenzer, 2011). The accuracy of both deliberate and intuitive judgements depends on the ecological rationality of the rule. Accordingly, more complex rules are not necessarily more accurate than simpler rules and statistical rules are not necessarily more accurate than heuristic rules. It has been found that relying on one good reason often results in more accurate predictions compared to complex approaches (Gigerenzer & Brighton, 2009). These results put heuristics on par with standard statistical models of rational cognition. Judgements that are intuitive (subjective estimations) and simple, can be more accurate than cognitive strategies that have more information (Evans, 2008; Kruglanski & Gigerenzer, 2011).

In the talent development process, aspects of the biological maturation play a crucial role. SA and anthropometric measurements, such as APHV and coaches' eye, evaluate different but related aspects of biological maturation during male adolescence. Given the relevance of maturity assessments in TD and TID, this study aimed to evaluate the agreement between classifications based on skeletal maturity, anthropometric measurements (e.g. APHV) and categorisations by coaches' eye.

Method

Sample

Participants were recruited from all the male soccer players who were invited to the under-15 national selection day for the Swiss Soccer Association during the 2012-2013 and 2013-2014 seasons. The players were selected from local clubs representing 13 regional squads (n = 226). From the regional squads, 144 players were selected to participate during the national selection days. Selection on all levels was based on the coaches' evaluation of the players' technical skills, game intelligence, personality and speed (Tschopp, Biedert, Seiler, Hasler, & Marti, 2003). The leader of the project asked all 144 players if they would like to participate in the study. Of those, 121 participants and their parents provided written informed consent. The participants were informed that participation was voluntary and that they could withdraw from the study at any time. An SA is not assigned to individuals who are skeletally mature, and mature individuals are usually excluded from SA studies (Malina et al., 2012; Roche et al., 1988). Therefore, after the SA assessment, two players were excluded from the study because they were assessed as being skeletally mature. The final cross-sectional sample included 119 (82.6%) participants. At the time of the study, all the participants were in good health and free of acute or known chronic diseases. The study was approved by the local research ethics committee and was in line with the Declaration of Helsinki.

Measurements

Weight, height, CA and SA were measured. Descriptive statistics of the participants are shown in Table 1. Height was measured with a fixed stadiometer (Seca 217; Seca, Hamburg, Germany), and weight was measured with calibrated scales (Tanita WB-110 MA; Tanita, Tokyo, Japan). Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. Players wore shorts and a t-shirt, and they removed their shoes. Two measurements were taken for each anthropometric variable on the same day as the radiograph. If the results differed by more than 4 mm for height and 0.4 kg for weight, the procedure was repeated. The two findings for each anthropometric measurement were averaged. All of the hand-wrist X-rays scans were performed at the Swiss Olympic

Medical Centre Magglingen, according to hand-wrist guidelines for SA (Martin et al., 2011).

Table 1.
Subject Characteristics

Characteristic	Mean (SD)	95% CI		Range	
CA (years)	14.0 (0.3)	13.9,	14.1	13.3	- 14.3
Height (cm)	164.9 (8.4)	162.8,	167.0	150.1	- 184.4
Weight (kg)	53.0 (8.7)	50.8,	55.2	37.8	- 73.4
SA (years)	13.9 (1.1)	13.5,	14.2	11.7	- 16.4

Note: CA = chronological age; SA = skeletal age; CI = confidence interval.

Procedure

Skeletal age. With the participants sitting beside the X-ray device (Stadler SE 4600; Stadler, Littau, Switzerland), the left hand-wrist was placed on a double-layered phosphor cassette without any radial or ulnar deviance. In order to assess all epiphyses, the X-ray tube was focused on the metacarpus. Using this standardisation, posterior-anterior radiographs of the left hand-wrist were taken with an X-ray device. A standardised modus of 42 kV tube voltage and 1.60 mAs, with a radiation time of 0.78 s, was used. All the films were rated by two independent, trained raters (R1, R2), using the radius-ulna-short bone protocol of Tanner et al. (2001) (TW3). The intra-rater difference in SA was 0.01±0.02 years and the inter-rater difference was 0.1±0.05 years.

SA was assessed by comparing the maturity indicators on each participant's X-ray scan to the standardised reference pictures according to the TW3 radius, ulna and short bone (RUS) method (Tanner et al., 2001). This method uses a detailed shape analysis of 13 bones, leading to their individual classification into one of several stages. Scores are derived from each bone stage. All the single bone scores were totalled and used for the overall classification. SA was assessed with a maximum precision of 0.1 years.

Using SA, the players were classified as early, on-time (average) or late maturation on the basis of the difference between SA and CA. On-time maturation was defined as an SA within 1.0 year of CA. Early maturation was defined as an SA older than CA by more than 1.0 year. Late maturation was defined as an SA younger than CA by more than 1.0 year.

Age at peak height velocity. The APHV was calculated as the difference between the CA and the predicted time (in years) from PHV. APHV is an indicator of biological maturity representing the time of maximum growth during adolescence. Predicted age based on APHV was estimated as CA minus maturity onset, as described by Mirwald et al. (2002). In this study, the mean age at PHV for the three samples adjusted for sample sizes was 13.8 years. Standard deviation (SD) for ages at PHV in longitudinal studies was about 1.0 year (Malina & Beunen, 1996; Malina et al., 2004). Using the values, on-time maturation was defined as a predicted age at PHV within ± 1.0 years (one SD). Therefore according to previous studies, on-time maturation was defined as an APHV between 13.8 ± 1 years or between 12.8 years and 14.8 years. Late maturation was defined as an APHV > 14.8 years and early maturation was defined as an APHV < 12.8 years.

Coaches' eye. Estimations of biological maturation were conducted subjectively by all assigned six national coaches, who are responsible for the national teams (U-15 to U-21). Classification was performed according to the categories of SA-CA and APHV into late, on-time and early maturation (Malina et al., 2012; Sherar et al., 2010). The coaches were instructed to record their estimation on a rating sheet. The coaches did not receive any other instruction or explanation about estimating the players' biological maturation. All the coaches had more than five years' experience, and each had attained the highest level of sport-specific education. All the coaches conducted their estimations independently, and they had no conflict of interest (e.g. relationships with the players). The inter-rater reliability of the coaches' classifications was excellent (ICC>0.95).

Statistical analysis. The classification procedure for early, on-time and late maturation corresponded to previous studies that used SA to classify youth athletes into maturity categories (Malina, et al., 2012; Sherar et al., 2010). According to the study of Malina et al. (2012), Kappa coefficients (k), Spearman rank order correlations (r_s) and proportions of agreement were calculated to estimate the agreement between classifications. For the k values, values >0.80 denoted almost perfect agreement, values >0.6 and <0.8 denoted substantial agreement, values >0.4 and <0.6 denoted moderate agreement, values >0.2 and <0.4 denoted fair agreement, values >0 and <0.2 denoted slight agreement and values <0 denoted poor agreement (Landis & Koch, 1977). Values are expressed as mean ± SD. Statistical analysis was performed using SPSS version 21 (IBM SPSS, Chicago, IL, USA). The level of significance was set at P<0.05.

Results

The SA of the players was 13.9 ± 1.1 years, and SA did not differ significantly from CA. Using SA, 24 players were classified as early maturation, 70 as on-time maturation and 25 as late maturation. Calculations of APHV resulted in eight players with early maturation, 105 with on-time maturation and six with late maturation. Mean APHV was 13.9 ± 0.3 years. The estimation by coaches' eye resulted in 11 players with early maturation, 91 with on-time maturation and 17 with late maturation.

The cross-tabulations of maturity status classifications based on SA-CA and by coaches' eye are summarised in Table 2. The agreement between the SA-CA classifications and the estimations by coaches' eye is 73.9%. The Spearman rank-order correlation between maturity classifications is strong (0.62). The Kappa coefficient is 0.48, which indicates moderate agreement.

Table 2.
Maturity categories by skeletal age and coaches' eye

Maturity categories from SA-CA	Maturity categories by coaches' eye				Agreement (%) [96% CI]	rs	Cohen's kappa	Magnitude
	Late	On time	Early	Total				
Late	13	12	0	25				
On time	4	65	1	70	73.9 [65.4, 81.0]	0.62	0.48	moderate
Early	0	14	10	24				
Total	17	91	11	119				

On time (average) is as a skeletal age within+1.0 year of chronological age; late is a skeletal age behind chronological age by more than 1.0. year; early is a skeletal age in advance of chronological age by more than 1.0 year.

Cross-tabulations of maturity status classifications based on SA-CA and APHV are summarised in Table 3. The agreement between the SA-CA classifications and APHV is 65.5%. The Spearman rank-order correlation between maturity classifications is moderate (0.42). The Kappa coefficient is 0.25, which indicates fair agreement.

Table 3.
Maturity categories by skeletal age and age at peak height velocity

Maturity categories from SA-CA	Maturity categories by age at peak height velocity				Agreement (%) [96% CI]	rs	Cohen's kappa	Magnitude
	Late	On time	Early	Total				
Late	6	19	0	25				
On time	0	67	3	70	65.5 [56.6, 73.5]	0.42	0.25	fair
Early	0	19	5	24				
Total	6	105	8					

On time (average) is as a skeletal age within+1.0 year of chronological age; late is a skeletal age behind chronological age by more than 1.0. On time (average) is an age at peak height velocity within +1 standard deviation of the mean age at peak height velocity; late is a peak height velocity of more than 1 standard deviation; early is a peak height velocity of more than -1 standard deviation.

Cross-tabulations of the maturity status classifications based on coaches' eye and APHV show an agreement of 78.2% (Table 4). The Spearman rank-order correlation between the maturity classifications is moderate (0.41). The Kappa coefficient is 0.30, which indicates fair agreement.

Table 4.
Maturity categories by coaches' eye and age at peak height velocity

Maturity categories by coaches' eye	Maturity categories by age at peak height velocity				Agreement (%) [96% CI]	rs	Cohen's kappa	Magnitude
	Late	On time	Early	Total				
Late	5	12	0	17				
On time	1	85	5	91	78.2 [69.9, 84.7]	0.41	0.3	fair
Early	0	8	3	11				
Total	6	105	8					

On time (average) is as a skeletal age within+1.0 year of chronological age; late is a skeletal age behind chronological age by more than 1.0. On time (average) is an age at peak height velocity within +1 standard deviation of the mean age at peak height velocity; late is a peak height velocity of more than 1 standard deviation; early is a peak height velocity of more than -1 standard deviation.

Discussion

There is little doubt that maturity assessments are an important aspect of TID. In our study, the coaches' eye had moderate agreement and a strong correlation with the SA categorisation, and was even better than the widely used APHV assessment. Therefore, a coaches' eye method seems to be an acceptable alternative to X-ray and APHV for classifying maturity in youth athletes. The SA of the players was 13.9 ± 1.1 years, and SA did not differ significantly from CA. The APHV method only showed fair agreement.

Many young, talented athletes go unnoticed and often drop out of soccer early because of delayed maturation. Consequently, there is a severe loss of talented young soccer players. Given the need to consider the maturation characteristics in any TID or TD program, appropriate ways to assess the maturity of young athletes should be established. This study fulfilled these requirements by demonstrating that a simple, subjective classification by coaches' eye could be a valid method to assess the maturation of young athletes. BA, determined using either non-invasive or invasive measures, can give a coach and medical staff an indication of the player's maturity in comparison to peers in the same age group. This information can be used for talent selection and to determine critical periods for training in terms of long-term talent development.

Skeletal age

The present study determined SA using the TW3 method. The SA results were generally consistent with previous studies of Brazilian (Teixeira et al., 2015), French (Carling, Le Gall, & Malina, 2012), Japanese (Hirose, 2009), and Portuguese players (Figueiredo et al., 2009b). In mid-adolescence, the full spectrum of skeletal maturity from early through late maturation is apparent. In our study, SA was similar to CA and the majority of players were found to have average, on-time maturation. Players with early and late maturation were slightly over-represented in comparison to the general population, but this trend was not significant.

However, in our study, the distribution of BA was different from other studies investigating youth soccer players. Those studies showed that coaches are more likely to select and promote average and early maturing boys (Figueiredo et al., 2009b; Malina et al., 2004; Malina et al., 2012). A possible reason for this difference is the TID program of the Swiss Soccer Federation, which defines BA as the stage of late childhood.

Other researchers have detected a mean bone age of 14.2 years in youth soccer players in the Under-13 category, and some of the athletes in that category had a bone age of 16.4 years (Hansen, Klausen, Bangsbo, & Muller, 2010). When comparing elite athletes in the Under-14 category with contrasting maturity status (i.e. late vs. early), a difference of 3.7 years was observed in bone age. In terms of anthropometric dimensions, this is a difference of 14 cm in height and 22 kg in body mass (Reilly, Bangsbo, & Franks, 2000). Figueredo et al. (2009) analysed the BA of 11- and 12-year-old soccer players and showed mean differences of 3.5 years between early and late maturity. These results are in line with our study, which found a mean difference of 3.7 years for BA.

Classifications in maturity categories

Classifications of youth soccer players into contrasting maturity categories (early, on-time, late) on the basis of predicted APHV have already been validated against classifications based on X-rays in youth soccer players. Malina (2012) analysed the relationships among indicators of biological maturation and the agreement between classifications of maturity status of two age groups of youth soccer players. In that study, the data included SA assessed by the FELS method, stage of pubic hair, predicted APHV, and percentage of predicted adult height. The Kappa coefficients were low (0.02–0.23) and indicated poor agreement between the maturity classifications. The Spearman rank-order correlations between categories were low to moderate (0.16–0.50). Although the indicators were related, the agreement of maturity classifications between SA and the predicted APHV was poor.

In line with previous studies, our classifications for SA-CA and predicted APHV were based on the SD of approximately 1 year (Malina et al., 2004).

Age at peak height velocity

In our study, mean APHV was 13.9 ± 0.3 years, which is in line with the findings from previous studies (Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009a; Malina et al., 2012; Teixeira et al., 2015). The limited agreement between maturity classification based on APHV and SA was likely due to the reduced standard deviations for APHV compared with that in the samples from which the protocol was developed. Additionally, the APHV distributions were relatively narrow. Therefore, the sensitivity and specificity used to differentiate players by maturity status of the offset protocol has been questioned, and validation studies on Polish youth followed from 8 to 18 years indicated several limitations (Malina, Rogol, Cumming, Coelho e Silva, & Figueiredo, 2015). Maturity offset has been suggested as a categorical variable, pre- or post-PHV (Mirwald, 2002). This appears to be a useful way to average PHV in maturing boys near the time of actual PHV within a narrow range of PHV ± 1 year (Malina & Kozieł, 2014). However, its utility is limited in practice (Malina et al., 2004; Malina et al., 2006).

The classification of players into maturity groups on the basis of predicted APHV was found to be fairly related to the SA classifications. Because the majority of players (over 88%) were classified as on-time maturation, the practicability of the method to categorise youth soccer players into maturity groups is called into question (Malina & Kozieł, 2014). This reflected the reduced range of variations in APHV. The observation that the APHV protocol did not correspond, at least moderately, impacts the practical application of its use in TD programs (Malina et al., 2012).

Both maturity indicators used in the present study measured different, but related, aspects of biological maturation during male adolescence. SA reflects the maturation of the bones of the hand-wrist. In contrast, APHV is an indicator of the timing of the maximal rate of growth in height during the growth spurt.

Coaches' eye

Classifications of biological maturity by coaches' eye correlated moderately with the SA classifications. Experienced coaches seemed to estimate the maturity of young soccer players better than the widely-used APHV method. In fact, the construct of biological maturation is very complex. It consists of the skeletal system, specifically ossification of cartilaginous endochondral bones, as well as aspects of sexual maturation, specifically hormonal status. It also includes indicators of somatic maturation, specifically progress in height and the tempo and timing of growth during the growth spurt. Thus, biological maturation is a very complex system of status, tempo and timing. The advantage of this intuitive approach used by the coaches lies in its holistic character and in its practicability. The coaches' judgement focuses on the person, as a whole. Thus, it integrates a variety of critical elements that determine maturity. Although maturation is complex, the inter-rater reliability of the coaches was excellent. Even more, current research shows that intuitive judgements are valid, which supports subjective assessments of coaches (Gigerenzer & Brighton, 2009; Kruglanski & Gigerenzer, 2011).

The weakness of this appraisal appears to be its subjective nature, even though we have to be conscious that this intuitive judgement is also based on an internal frame of reference built on relevant knowledge (Buekers, Borry, & Rowe, 2015).

Limitations and strength of the study

This study examined 119 male soccer players in a highly selective sport setting and very experienced coaches. All national coaches had more than five years' experience, and each had attained the highest level of sport-specific education. Therefore, the results cannot be transferred to the general population and need further confirmation. However, one strength of our study is that the male soccer players who participated were in an age range that showed the greatest variations of maturity, and the consideration of maturity characteristics in the selection process is very important. The coaches' eye is very practical, and it uses a holistic approach for the classification of biological maturation. It may be potentially useful in affording more opportunities to players who are less mature than their peers and in developmental programs where technically skilled, yet less mature, players may be overlooked due to maturity-associated limitations in physical and functional capacities (smaller size, and less strength, power and speed). This is important in early- and mid-adolescence, when selection processes are executed (Figueiredo et al., 2009b). We expect our results to be valid for other youth elite sports; however, this topic needs further study.

In the current system with early selection processes, late maturing players may be dismissed on the basis of their physical characteristics. Therefore, modern models of TID and TD have to integrate the maturation characteristics of young athletes into the selection process (Reilly, Williams, et al., 2000; Unnithan et al., 2012; Vaeyens et al., 2008). At a young age (less than 12 years), the APHV is not valid and the measurement of SA is often ethically and financially unjustifiable. A classification and integration of biological maturity using coaches' eye could be a first step towards fairer and more efficient identification and development of young athletes. Since the aim of a federation or club is to identify and develop promising young players who can later progress to an elite team, it is crucial that talent models have the ability to distinguish between the current performance levels of players and their future potential (Vaeyens et al., 2008).

Conclusion

TD programs call for implementing biological maturity into the TID process. Thus, there is a need to classify youth into early, on-time and late maturation stages for TID and to design training and competition programs. Many soccer clubs and soccer federations already select their players based on the subjective assessments of scouts and coaches. However, these subjective assessments are often biased toward selecting players with early biological maturation, because that maturity status strongly correlates to the development of physical attributes, motor ability and some specific soccer skills. Our results show that coaches' eye is a valid method to assess biological maturation. Coaches' eye was even better than the widely-used APHV assessment. In comparison to the classical X-ray method, coaches' eye offers much quicker information gathering, lower costs and no exposure to radiation. In sports, a systematic and broad implementation of maturity classifications could have a significant impact on performance assessment, evaluation, selection and training during athlete development.

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