Soccer coaches vs. sport science and medicine staff: who can more accurately predict the skeletal age of high-level youth soccer players?

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Abstract

***Purpose**:* Biological maturity is an important aspect in the context of talent identification and development processes within elite youth soccer players. The aim of this study was to investigate the accuracy of soccer coaches (SC) as well as sport science and medicine staff (SSMS) to predict the skeletal age of high-level youth soccer players. We also aimed to evaluate the inter-rater reliability of the skeletal age predictions among the SC and SSMS.

Methods: Skeletal ages were collected for 89 male academy soccer players registered for the U12 to U16 age groups at a professional German Bundesliga club. In addition, twelve SC and five SSMS provided their skeletal age predictions for each player of their respective age group. Standardised mean differences and equivalence testing were performed between actual and predicted skeletal ages. Intra-class correlations (ICC) were calculated to assess the inter-rater reliability.

Results: For the SC, differences between predicted and actual skeletal ages were trivial and equivalent to zero for the U12, U14 and entire sample, while for the SSMS, standardised mean differences ranged from trivial to small for all age groups and the entire sample. ICC for skeletal age predictions for the entire sample was good among the SC and excellent among the SSMS, but was somewhat lower when age groups were analysed separately.

Conclusion: While, on average, predictions were close to the actual skeletal age, SC were slightly more accurate than the SSMS. However, variability among the SSMS was large on an individual level.

Key Words: maturation, adolescence, talent identification, development

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Introduction

The ongoing assessment of biological maturity, defined as the progress towards the biologically mature or adult state (15), is an important aspect in elite youth soccer talent identification and development processes. Youth soccer players within the same chronological age group can vary substantially in maturity status (i.e. the state of maturation at the chronological age of observation), with some players maturing in advance or delay compared to their peers (11,20), which has implications for several key stakeholders working with elite youth soccer players to maximise sporting talent (17) while minimising injury risk (12).

Growth rates and particularly differential growth in different body systems as well as maturity status have been shown to influence injury rates in elite youth athletes with increased overall injury rates observed during the growth spurt and for early maturing athletes as week as increased lower limb apophyseal injury risk for late maturing athletes (12,24,28,36). The appropriate adjustment of training load and content by the sport science and medicine staff (SSMS) during this period has been suggested to mitigate injury risk and facilitate player development (13). Moreover, growth-related injuries are aligned with the distal to proximal growth pattern of the lower limbs (23,28). It is therefore essential to be aware of the biological maturity status of elite youth soccer players to optimise player development by designing targeted injury prevention programs.

Inter-individual differences in biological maturity status also impact physical capacities particularly during the adolescent growth spurt, whereby more advanced players perform, on average, better in tests of strength, power, and speed (6,18,26). As a consequence, early maturing players, particularly during the adolescence, might be perceived as more talented and therefore recruited by soccer coaches (SC) while more skilled but late maturing players tend to be overlooked, de-selected or drop out (5,10,38). Therefore, inter-individual maturity-associated differences in physical performance present challenges for SC with identifying and contextualising current talent of young soccer players.

Various methods exist to estimate the biological maturity status of young soccer players (7). Traditionally, skeletal maturity to derive skeletal age (SA) from the bones of the hand and wrist viewed on a standard radiograph and sexual maturity which requires the athlete to self-report or a clinician to evaluate the athlete’s secondary sex characteristics as indicators of biological maturity have been implemented in research settings (17). While both methods are valid in assessing the biological status, they also present clear disadvantages in that they are considered invasive, costly, time consuming, and typically require trained physicians (21). Thus, it has become increasingly common for practitioners to adopt non-invasive, anthropometric-based methods. Although there are several prediction equations, two methods are predominately used across soccer academies, that is percentage of predicted near adult height and predicted maturity offset (33). However, both methods have significant limitations and require further validation and care in application (21).

Another non-invasive method in estimating the biological maturity status is eyeballing, i.e. the visual evaluation of young soccer players. During adolescence a general pattern is visible whereby the more distal segments of the lower limbs grow first, followed by the lower extremities and finally trunk and shoulders (34). Visually inspecting the development of these body segments will provide insights regarding the maturity status of an athlete. As there is no equipment required, such evaluations can be done by all practitioners working daily with athletes such as SC or the SSMS. Importantly, this method does not remove the necessity to regularly assess biological maturation through objective methods, but rather complements them in situations in which obtaining objective data on biological maturation is no possible. In addition, complementing subjective estimations with objective data on biological maturity can be considered as an informative education tool for SC, SSMS, and other key stakeholders involved in identifying, selecting, and developing talent. Limitations of this method include potential cognitive biases affecting the interpretation and judgement of the maturity status of an athlete. A recent study found moderate agreement between actual skeletal ages and predicted skeletal ages when players were classified as early (skeletal age older than chronological age by >1.0 years), on-time (skeletal age within ±1.0 years of chronological age), and late (skeletal age younger than chronological age by >1.0 years) maturing U15 male soccer players (31). However, they only included one single age group (i.e., U15) limiting the generalisation to younger and older age groups as differences in body appearance and composition are less pronounced in these age groups (6,8). In addition, the application of somewhat arbitrary bands to classify players as early, on-time, and late maturing leads to a loss of information as this underestimates the extent of variation each band and players close to but on opposite sides of the threshold are characterised as being very different rather than very similar (1).

In light of the previous discussion, the primary aim of the current study was to investigate the accuracy of academy SC as well as SSMS to predict the skeletal age of high-level youth soccer players during adolescence. A secondary aim was to evaluate the inter-rater reliability of the skeletal age predictions among the academy SC as well as the SSMS.

Materials and methods

Participants

The sample included 89 male academy soccer players (chronological age mean ± standard deviation (SD): 13.3 ± 1.4 years, standing height: 163.0 ± 12.5 cm, body mass: 51.1 ± 12.9 kg) registered for the U12 to U16 age groups at a professional German Bundesliga club. The majority of players were identified as Caucasian (n=74), while a minority had an African (n=6) and Middle Eastern ancestry (n=9). Players were grouped in chronological age groups of 12-month bands, ranging from January to December. Besides the players, all SC (head and assistant coaches, n=12, 6.9 ± 3.8 years' experience, U12: n=2, U13: n=2, U14: n=2, U15: n=3, U16: n=3) and SSMS (physiotherapists and sport scientists, n=5, 9.9 ± 11.5 years' experience, U12: n=2, U13: n=2, U14: n=2, U15: n=2, U16: n=2) responsible for their respective age groups participated in this study. Of note, SSMS were responsible for two to three age groups and rated therefore multiple age groups. Data were collected as part of the routine player monitoring procedures of the youth academy so that ethical approval was not required (37). Upon enrolment of each player, parents/guardians signed contracts providing consent and assent confirming that data arising as a condition of regular player monitoring procedures can be used for research and publication purposes.

Study design

This study followed an observational, cross-sectional approach. All data were collected before each training session at the same time of the day to reduce the effect of circadian rhythm upon anthropometric measurements (29). Within a time interval of three weeks, standing height, body mass and skeletal age were measured. All SC and SSMS provided their skeletal age predictions within one week after the skeletal age assessment.

Procedures

Anthropometry

Standing height (±0.1 cm) and body mass (±0.1 kg) were measured by three physiotherapists of the respective age groups using a portable stadiometer with integrated weighing scale (Kern MPE-E, KERN & SOHN GmbH, Balingen, Germany). Standardised procedures according to the guidelines of International Society for the Advancement of Kinanthropometry (ISAK) were followed. The players wore shorts and a T-shirt, footwear was removed. Standing height for a sub-sample of ten players per age group was measured again separated by seven days to assess intra-rater test-retest reliability. The standard error of measurement (SEM) for the three examiners was 0.31 cm (95% confidence interval 0.24 to 0.46 cm), 0.49 cm (0.33 to 0.89 cm), and 0.23 cm (0.16 to 0.42 cm), well within previously reported data of similar populations (14,22).

Skeletal age

The BAUS^{TM} system (SonicBone Medical Ltd., Israel) was used to estimate skeletal age (± 0.1 years) through measuring bone density at three sites of the left hand: wrist, meta-carpals and third phalanx. Details of the method are described elsewhere (32). Briefly, the device measures two parameters: speed of propagation through bone of high frequency waves and the reduction in amplitude of this high frequency wave as a function of distance through the bone. Skeletal age was then automatically computed based on the Tanner-Whitehouse II (TW2) method (35). Measurements were performed by the same trained examiner (C.K., not included in the sample of SC nor SSMS). Intra-rater test-retest reliability of the skeletal age assessment was calculated for a sub-sample of 17 players prior to data collection. The standard error of measurement for skeletal age was 0.13 years (95% confidence interval 0.10 to 0.20 years), consistent with previously reported data (6,19).

Prediction of skeletal age by soccer coaches and sport science and medicine staff

One day after of the skeletal age assessment, all SC as well as SSMS were asked to predict the skeletal ages (±0.1 years) within one week for the players of their respective age groups. A custom-made spreadsheet was used, and all SC as well as SSMS were instructed to independently rate the players of the age group(s) they were affiliated with based on their experience from working within the youth academy setting. No further educational instruction was provided. Head and assistant coaches were grouped together and termed *soccer coaches* (SC) while sports scientists and sports physiotherapists were grouped together and termed *sport science and medicine staff*. The average skeletal age for each player were calculated among SC and SSMS separately, which were then used for further analyses. SC had no experience with results derived from the skeletal age measurements, while verbal and informal feedback from the 1-3 skeletal age assessments of the U12 to U16 age groups from the previous season were provided to SSMS after each assessment.

Statistical analyses

Descriptive statistics are presented as mean ± SD. Positive values in sign (+) suggested an over-prediction, whereas negative values (-) indicated an under-prediction of the actual skeletal age. Standardised mean differences with 95% confidence interval (CI) for the entire sample and each age group were calculated to assess the difference between actual skeletal ages and predicted skeletal ages by the SC and SSMS. Further, equivalence testing was performed to assess the statistical equivalence of the difference between actual and predicted skeletal ages against the smallest effect size of interest (SESOI). Based on previous literature (6,19), a SESOI of ±0.3 years was used to specify the upper and lower equivalence bounds and a confidence level of 0.1. Pearson product-moment correlations (r) were calculated between the difference of actual skeletal ages and chronological ages and the difference between the actual skeletal ages and predicted skeletal ages by the SC and SSMS. Finally, two-way random effects, consistency, single rater intra-class correlations (ICC) were calculated to assess the inter-rater reliability of predicted skeletal ages among the SC and SSMS, respectively. Magnitudes for standardised mean differences were interpreted as follows: ≤0.2 as trivial, >0.2–0.6 as small, >0.6–1.2 as moderate, and >1.2 as large. The following scale was adopted to interpret the magnitude of r: ≤0.1 as trivial, >0.1–0.3 as small, >0.3–0.5 as moderate, >0.5–0.7 as large, >0.7–0.9 as very large, and >0.9–1.0 as almost perfect. ICC was interpreted using the following thresholds: ≤0.50 as poor, >0.50–0.75 as moderate, >0.75–0.90 as good, and >0.90–1.00 as excellent. Analyses were performed with Rstudio (version 1.3.1056, R Foundation for Statistical Computing, Vienna, Austria) using the following packages, MOTE (version 1.0.2), TOSTER (version 0.34), and irr (version 0.84.1).

Results

Actual skeletal ages and predicted skeletal ages by the SC and SSMS plotted relative to chronological age are shown in Figure 1. Descriptive statistics, standardised mean difference and equivalence testing are summarised in Table 1. For the SC, standardised mean differences between predicted and actual skeletal ages were trivial and equivalent to zero for the U12, U14 and entire sample. Small standardised mean differences and non-equivalent results to zero were observed for the U13, U15 and U16 age groups. For the SSMS, standardised mean differences ranged from trivial to small, but were non-equivalent to zero for all age groups and the entire sample.

There were very large correlations between the difference of actual skeletal ages and chronological ages and the difference between the actual skeletal ages and predicted skeletal ages for both the SC (Figure 2, panel A) and the SSMS (Figure 2, panel B). Regarding the SC, correlations were very large for the U12 (r = -0.83 (95%CI -0.94 to -0.56), U15 (r = -0.86 (95%CI -0.94 to -0.68) and U16 (r = -0.78 (95%CI -0.91 to -0.51) age groups, large for the U13 (r = -0.62 (95%CI -0.85 to -0.17)) and moderate for the U14 age group (r = -0.34 (95%CI -0.71 to 0.16)). For the SSMS, correlations were very large to almost perfect for the U12 (r = -0.92 (95%CI -0.97 to -0.77), U13 (r = -0.95 (95%CI -0.98 to -0.86), U15 (r = -0.84 (95%CI -0.93 to

-0.64) and U16 (r = -0.80 (95%CI -0.92 to -0.54) age groups and large for the U14 age group (r = -0.64 (95%CI -0.86 to -0.23)).

Figure 3 shows the inter-rater ICCs among the SC and SSMS by age group. ICC for skeletal age predictions across all age groups for the entire sample was good among the SC (ICC = 0.85, 95% CI 0.76 to 0.91) and excellent among the SSMS (ICC = 0.93, 95% CI 0.89 to 0.95). When age groups were analysed separately, moderate to excellent inter-rater ICCs were observed among the SC (ICC = 0.53 to 0.90). In contrast, inter-rater ICCs among the SSMS were poor to moderate across the age groups (ICC = 0.37 to 0.72).

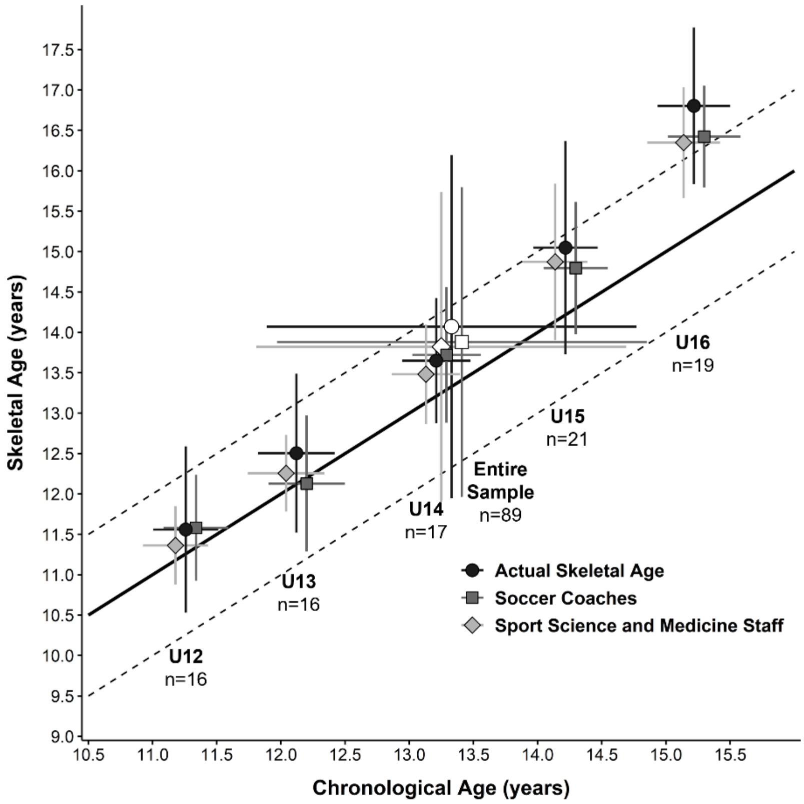

Figure 1. Mean (±SD) actual skeletal ages and mean (±SD) predicted skeletal ages by the soccer coaches and sport science and medicine department plotted relative to mean (±SD) chronological age in high-level youth soccer players by age group. Dashed lines indicate thresholds to classify players as late (< -1.0 years), on-time (> -1.0 to < +1.0 years), and early (> +1.0 years).

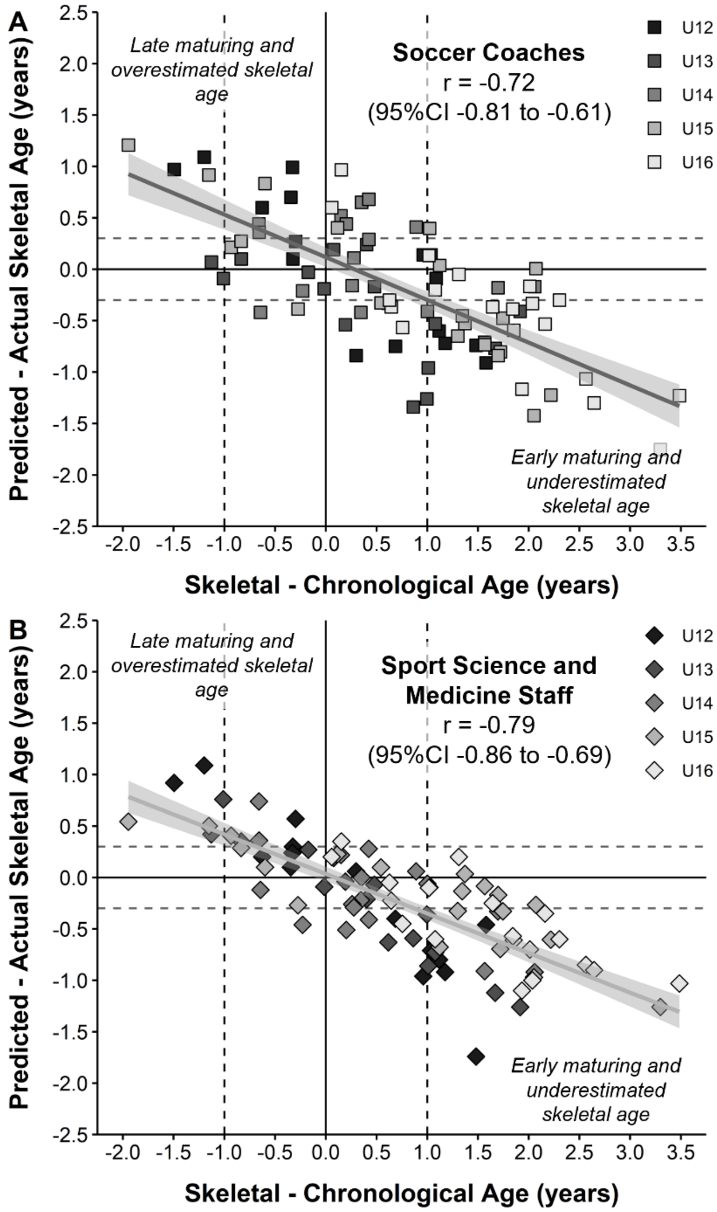

Figure 2. Individual differences between actual skeletal ages and predicted skeletal ages plotted relative to the difference between actual skeletal ages and chronological ages for the entire sample by the soccer coaches (panel A) and sport science and medicine staff (panel B). Horizontal dashed lines indicate the smallest effect size of interest (SESOI), while vertical dashed lines indicate thresholds to classify players as late (< -1.0 years), on-time (> -1.0 to < +1.0 years), and early (> +1.0 years).

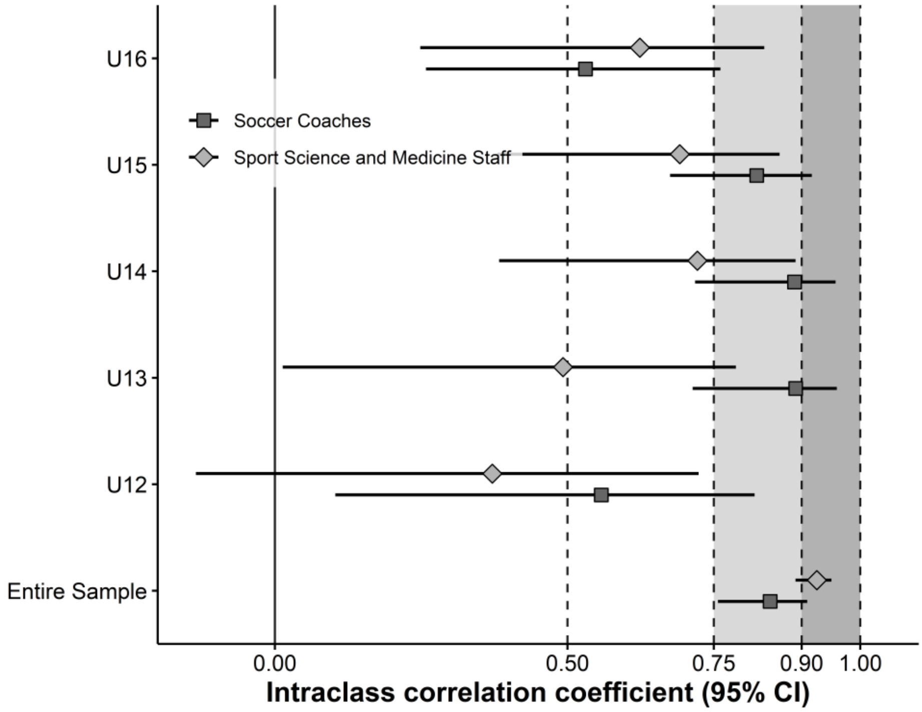

Figure 3. Inter-rater intra-class correlations (ICC) coefficients and 95% CI among the soccer coaches and sport science and medicine staff by age group. Number of raters were as follows for soccer coaches: U12: n=2, U13: n=2, U14: n=2, U15: n=3, U16: n=3. Number of raters were as follows for sport science and medicine staff: U12: n=2, U13: n=2, U14: n=2, U15: n=2, U16: n=2.

Discussion

The primary aim of the present study was to investigate the accuracy of skeletal age predictions of high-level youth soccer players by academy SC as well as SSMS. As a secondary aim, we evaluated the inter-rater reliability of the skeletal age predictions among the academy SC and SSMS. The first main finding of this study was that skeletal age predictions were, on average, close to the actual skeletal age for both SC as well as SSMS, although SC were slightly more accurate in their predictions. Another important finding was that skeletal ages of early maturing players were underestimated by both SC as well as SSMS while the skeletal ages of late maturing players were overestimated as indicated by the large to very large correlations between the difference of actual skeletal ages and chronological ages and the difference between the actual skeletal ages and predicted skeletal ages. Lastly, inter-rater reliability was age-group dependent for both SC and SSMS whereby poorer reliability was evident for the younger (U12, U13) and older (U16) age groups. Collectively, our findings highlight the need for further education and awareness particularly with regards to very early and late maturing players for both SC and SSMS to optimise talent identification and development processes.

Table 1. Descriptive statistics, standardised mean differences, equivalence tests between actual skeletal age and predicted skeletal age by the coaches in high-level youth soccer players by age group.

Age group	Chronological age (years; mean±SD)	Actual skeletal age (years; mean±SD)	Predicted skeletal age by the coaches (years; mean±SD)	Difference predicted-actual skeletal age (years; mean±SD)	Standardised mean difference (95% CI)	p value equivalence test
Soccer coaches						
U12	11.3±0.3	11.6±1.0	11.6±0.7	0.0±0.7	0.03 (-0.67; 0.72)	p=0.045 *
U13	12.1±0.3	12.5±1.0	12.1±0.8	-0.4±0.5	-0.41 (-1.01; 0.29)	p=0.727
U14	13.2±0.3	13.6±0.8	13.7±0.8	0.1±0.4	0.09 (-0.58; 0.76)	p=0.001 *
U15	14.2±0.3	15.0±1.3	14.8±0.8	-0.3±0.8	-0.23 (-0.84; 0.38)	p=0.391
U16	15.1±0.3	16.8±1.0	16.4±0.6	-0.4±0.6	-0.46 (-1.10; 0.18)	p=0.724
Entire sample	13.3±1.4	14.1±2.1	13.9±1.9	-0.2±0.6	-0.09 (-0.39; 0.20)	p=0.054 *
Sport Science and Medicine Staff						
U12	11.3±0.3	11.6±1.0	11.4±0.5	-0.2±0.8	-0.24 (-0.93; 0.45)	p=0.298
U13	12.1±0.3	12.5±1.0	12.3±0.5	-0.2±0.6	-0.32 (-1.02; 0.38)	p=0.363
U14	13.2±0.3	13.6±0.8	13.5±0.6	-0.2±0.4	-0.24 (-0.91; 0.44)	p=0.110
U15	14.2±0.3	15.0±1.3	14.9±1.0	-0.2±0.5	-0.15 (-0.76; 0.45)	p=0.120
U16	15.1±0.3	16.8±1.0	16.3±0.7	-0.5±0.4	-0.54 (-1.18; 0.11)	p=0.930
Entire sample	13.3±1.4	14.1±2.1	13.8±1.9	-0.3±0.5	-0.12 (-0.42; 0.17)	p=0.193

Notes: * indicates a significant equivalence test with alpha=0.10

Similar to previous research, our sample of high-level youth soccer players was, on average, advanced in skeletal relative to their chronological age (chronological age: 13.3±1.4 years, skeletal age: 14.1±2.1 years). While skeletal ages were on average slightly advanced in the U12, U13 and U14 compared to the chronological ages, this bias further increased in the U15 and U16 age groups. These data are consistent with previous observations of male youth players aged 11 to 17 years (9,11,32) although differences in skeletal ages between assessment protocols (i.e. Tanner-Whitehouse, Greulich and Pyle, and Fels method) need to be acknowledged (21). Our and previous data clearly demonstrate the selection bias favouring on-time and early-maturing players within older age groups. This highlights the importance for SC as well as SSMS to precisely predict the maturity status in case more advanced methods such as skeletal age assessments are not available to accurately identify, select and develop current and future talents.

Across the entire sample, SC predicted the actual skeletal age on average slightly more accurately than the SSMS who consistently underestimated the actual skeletal ages across all age groups as indicated by the trivial to small standardised mean and non-equivalent differences (see Table 1). While a recent study only included SC to predict skeletal ages for a single age group (i.e., U15), and employed a different methodological approach (i.e., categorisation of maturity status) they found moderate agreement in the accuracy to classify players as early, on-time or late maturing (31). In addition, we observed large individual variability in the differences between predicted and actual skeletal ages irrespective of the age group, as indicated by the wide confidence intervals of the standardised mean differences. For example for the predictions of the SC for the U12, the standardised mean difference was trivial (i.e., 0.03), however, confidence intervals ranged from moderately negative (i.e., -0.56) to moderately positive (i.e., 0.61). Similar wide confidence intervals indicating large uncertainty in the point estimate have been observed for the other age groups of both the SC and SSMS. This highlights that on an individual level, both SC and SSMS might substantially under- or overestimate the skeletal ages irrespective of the maturity status of the players (i.e., pre-, circa-, and post-pubertal). While no other research exists that allows direct comparison to our results, the lack of substantial differences between SC and SSMS is somewhat surprising. As the SSMS is typically responsible for collecting, analysing, and reporting growth and maturation data (33), they might have a greater formal knowledge base and understanding with regards to the different biological systems related to growth and maturation and in turn might have more accurate predictions. However, in our study, SC predicted, on average, skeletal ages slightly more accurately. An explanation could be that SC might offset the lack of formal education in the area of growth and maturation with their past experiences working with youth soccer players of varying or the same age group across multiple years within the academy setting (3). This allows coaches to accumulate a knowledge base by implicitly and intuitively observing a large number of youth soccer players of different skeletal maturity within and across age groups (25). Although, in our sample, SSMS had, on average, a larger working experience than SC while also working across 2 to 3 age groups allowing them to accumulate a diverse knowledge base across a wider range of skeletal maturity, they might rely solely on their theoretical knowledge. As SC are typically involved in decision-making processes that are characterised with great uncertainty, limited available information and time pressure, they developed, although prone to biases, an expertise in practical intuition to inform their decision-making (30). As such, SC heavily rely on their gut instinct to make decisions based on their tacit knowledge, which is informed by both objective and subjective information gained over time and has been shown as an important aspect in other areas such as talent identification (30). Thus, both sources of education are required, and it might be argued that combining them leads to more accurate predictions of youth soccer players.

Another finding of this study was that there were large to very large correlations between the difference of actual skeletal ages and chronological ages and the difference between the actual skeletal ages and predicted skeletal ages (see Figure 2). This suggests that the skeletal ages of early maturing players were underestimated, while skeletal ages of late maturing players were overestimated by both SC and SSMS. There is considerable inter-individual variation in skeletal maturity among youth soccer players 11–15 years of age (16). Differences between the skeletally least and most advanced player were 3.7, 3.5, 3.0, 5.2 and 3.5 years for the U12, U13, U14, U15 and U16 age groups which are in line with previous research (20). In contrast, these differences were much smaller for the predictions of the SC (2.1 to 3.3 years) and SSMS (1.9 to 3.4 years) across all age groups. This highlights that both SC and SSMS have difficulties to accurately predict the skeletal ages of those players who are late and early maturing. The accurate prediction of the skeletal ages of youth soccer players and in particular of early and late maturing players plays a significant role in the evaluation of talent identification and the development (2,26). For instance, maturity status has been shown to impact the evaluation of match performances by SC whereby advanced somatic maturity was associated with more positive coach match grades (10). Similarly, players advanced in biological maturity have on average superior sprint, strength, and power performances compared to later maturing players (6,26). Further, late maturing players have been identified to be at higher risk of sustaining bone and growth plate injuries, while early maturing players have the highest overall injury risk (24). Failing to accurately identify players as late or early maturing might cause issues when aiming to modify training content and load to reduce injury incidence. It is therefore crucial to precisely measure the current maturity status to appropriately evaluate the current sport-specific and physical performance level, estimate the potential future performance, and minimise injury risk.

Finally, we sought to assess the inter-rater reliability of the skeletal-age predictions among the SC and the SSMS. A clear age-group pattern was evident whereby we observed poorer reliability for the younger (i.e. U12 and U13) and older (i.e. U16) age groups. Typically, the majority of the U12 and U13 players are pre-pubertal (4,17), i.e. they have not entered the growth spurt. Similarly, given the on average advanced biological maturity in elite youth soccer academies (11,32), most of the U16 players can be classified as post-pubertal, i.e. they already experienced their growth spurt. In contrast, the most U14 and U15 players experience in these age groups their growth spurt which is associated with rapid changes in growth and physical development (4,27). We believe that the greater heterogeneity in actual skeletal ages in the U14 and U15 and thus inter-individual differences in body appearance and composition (e.g. muscle mass, ratio of leg to trunk length, shoulder girth) contribute to the more reliable predictions among SC as well as SSMS in these age groups. For example, while variation exists among pre- (i.e., majority of U12 and U13 players) and post-pubertal players (majority of U16 players), differences in body composition are less pronounced in these players compared to players from the U14 and U15, of which variation of players classified as pre-, circa- and post-pubertal is greatest (6,8). As such, identifying players based on visual inspection as early or late maturing within the pre- and post-pubertal stages is more challenging than for players during the growth spurt. This likely explains the higher inter-rater reliability within the U14 and U15 age group. Greater emphasis on identifying subtle differences in body composition within pre- and post-pubertal players is needed which allows a more homogenous prediction of skeletal ages of the same player within these age groups.

The findings of this study need to be viewed in the context of its limitations and potential sources of bias. Firstly, physiotherapists who measured anthropometrical data of the players were also included in the sample of SSMS which could lead to bias in their skeletal age predictions. Secondly, as SC and SSMS were aware of physiological test data (e.g., sprint performance) of their players, which are associated with biological maturity they might have entered the subjective component of the skeletal age prediction with an element of 'knowledge' which in turn may confound the findings presented here particularly given the small number of respondents involved. Thirdly, as SSMS received verbal and informal feedback from the previous 1–3 skeletal age assessments, predictions might have been biased towards more accurate estimations given the pre-existing information. Fourthly, given the long-term relationships between SC and SSMS and their players skeletal age predictions may be a result of 'watching the players grow' rather than purely based on momentaneous observations. Lastly, as SC and SSMS typically use in practice qualitative descriptions to categorise the maturity status of a player (i.e., early, on-time, late maturing), they might have been unfamiliar with the quantitative approach of skeletal age predictions. Whilst it might be more difficult to comprehend to quantitatively predict the skeletal age of a player, the aim was to understand whether SC and SSMS were able to estimate the skeletal ages with limited formal education and information related to biological maturation. Future research surrounding the potential impact of blinding the chronological age when predicting the skeletal age, assessing the influence of educational sessions upon the accuracy of the prediction, and extending the sample to other key staff members involved in the talent identification and selection process such as scouts should be considered when evaluating the method of estimating the biological maturity status through eyeballing the youth athlete.

Practical implications

While SC and SSMS rarely predicted an early maturing player as late and vice versa, a clear pattern was evident whereby skeletal ages of early maturing players were underestimated and late maturing players were consistently overestimated. This highlights the lack of awareness of the large inter-individual variation in skeletal ages which can be up to five years within one age group during adolescence. Although our SC and SSMS have several years of experience within the academy setting, our data suggest that strategies need to be implemented to provide formal education to SC and SSMS with regards to the differential status, timing and tempo of biological systems related to growth and maturity. This, in turn, will ultimately benefit SC, scouts and other key stakeholders in the context of identifying and selecting prospective players when the collection of objective data related to growth and maturity is not possible.

Conclusion

This study investigated the accuracy of skeletal age predictions by SC as well as SSMS of high-level U12 to U16 soccer players. In summary, the findings from this study suggest that on average SC predicted the skeletal ages slightly more accurately than the sport and medicine staff, although the accuracy on an individual level was poor. Moreover, findings suggest that both SC and SSMS equally underestimated and overestimated the skeletal ages of early and late maturing players, respectively. Together with the somewhat poor to moderate inter-rater reliability within age groups among SC and SSMS, our data highlight the importance of targeting educational strategies particularly with regards to better visually identifying very early and very late maturing players. While the objective assessment of biological maturity remains an important cornerstone in the routine player monitoring procedure, these findings might help SC and SSMS alike to optimise talent identification, selection, and development processes, in the circumstances in which obtaining objective information on biological maturation of a player is not feasible.

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Table Legends

Table 1. Descriptive statistics, standardised mean differences, equivalence tests between actual skeletal age and predicted skeletal age by the coaches in high-level youth soccer players by age group.

Figure Legends

Figure 1. Mean (±SD) actual skeletal ages and mean (±SD) predicted skeletal ages by the soccer coaches and sport science and medicine department plotted relative to mean (±SD) chronological age in high-level youth soccer players by age group. Dashed lines indicate thresholds to classify players as late (< -1.0 years), on-time (> -1.0 to < +1.0 years), and early (> +1.0 years).

Figure 2. Individual differences between actual skeletal ages and predicted skeletal ages plotted relative to the difference between actual skeletal ages and chronological ages for the entire sample by the soccer coaches (panel A) and sport science and medicine staff (panel B). Horizontal dashed lines indicate the smallest effect size of interest (SESOI), while vertical dashed lines indicate thresholds to classify players as late (< -1.0 years), on-time (> -1.0 to < +1.0 years), and early (> +1.0 years).

Figure 3. Inter-rater intra-class correlations (ICC) coefficients and 95% CI among the soccer coaches and sport science and medicine staff by age group. Number of raters were as follows for soccer coaches: U12: n=2, U13: n=2, U14: n=2, U15: n=3, U16: n=3. Number of raters were as follows for sport science and medicine staff: U12: n=2, U13: n=2, U14: n=2, U15: n=2, U16: n=2.