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ORIGINAL RESEARCH

Normative Reference Centiles for Sprint Performance in High-Level Youth Soccer Players: The Need to Consider Biological Maturity

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Purpose: To compute reference centiles for 5- and 30-m sprint times relative to chronological and skeletal age in youth soccer players. Subsequently, to compare individual's sprint performance scores derived from the chronological and skeletal age reference centiles. ***Methods***: Sprint times were collected for a sample of male U11 to U19 soccer players ($n = 1745$ data points). Skeletal age data were available for a subsample ($n = 776$ data points). Reference centiles were fitted using generalized additive models for location, scale, and shape. Individual z scores relative to chronological and skeletal age reference centiles were computed and compared for each maturity group (late, on-time, early, and very early) using standardized mean differences (SMD). ***Results***: Reference centiles for chronological age increased more rapidly between 10.5 and 15.5 years, while reference centiles for skeletal age increased more rapidly between 13.0 and 16.5 years. Differences in chronological and skeletal z scores for very early (SMD: −0.73 to −0.43) and late (SMD: 0.58 to 1.29) maturing players were small to large, while differences for early (SMD: −0.30 to −0.19) and on-time (SMD: 0.16 to 0.28) were trivial to small. ***Conclusion***: Reference centiles provide a valuable tool to assist the evaluation of sprint performance in relation to chronological and skeletal age for talent identification purposes in youth soccer players.

Keywords: adolescence, speed, skeletal age, percentiles, reference values

Key Points

- Reference centiles for 5 and 30 m provide objective references for practitioners to better interpret the sprint performance of youth soccer players in relation to chronological and skeletal age.
- Sprint performance showed a small to moderate reduction for very early maturing players and moderate to large improvement for late maturing players when expressed relative to skeletal age reference centiles.
- Our findings substantiate the importance to contextualize sprint times relative to biological maturity to avoid misinterpreting sprint performance of adolescent athletes, particularly for age groups with considerable variability in skeletal maturity (ie, U13–U16).

The assessment of physical performance is an important element in the talent identification and development processes in highly trained youth soccer players (34). One key component considered to be of high relevance to overall performance in soccer is linear sprint performance (13,29). Thus, training and assessing linear sprint performance is a standard component of routine physical performance programs and testing batteries in high-performance soccer academies. Typically sprint tests range from 20 to 40 m including various split times at shorter distances such as 5 m allowing the assessment of acceleration and maximum sprinting speed which are considered as 2 distinct components of sprint performance (5).

Previous research showed that developmental changes in sprint performance follow a nonlinear trajectory throughout adolescence (21). These changes are influenced by the adolescent growth spurt occurring, on average, at around 14 years (28) resulting in a rise of hormonal levels (eg, testosterone) and musculotendon properties (eg, muscle size, pennation angle, fascicle length, tendon stiffness, motor unit recruitment, and preactivation) (15,39). As such, improvements in sprint performance have been reported to be greater for athletes during the adolescent growth spurt compared with those prior to and after the adolescent growth spurt (32).

In high-performance youth soccer academies, there is a general appreciation toward the importance of assessing biological maturation (45), defined as the progress toward the biologically mature or adult state (23). Youth soccer players within the same chronological age group vary considerably in maturity status (ie, the state of maturation at the chronological age of observation), with some players maturing in advance or delay compared with their peers (27,43). Given the association between biological maturation and physical performance, biologically more mature athletes within the same chronological age group perform, on average, better in linear sprint tests (14,26,33). For example, an early maturing player might perform better than the majority of his peers of the same chronological age, but when compared with those of the same maturity status, his sprint performance can be described as average. Conversely, the sprint performance of a late maturing athlete might be interpreted as substantially better when compared with peers of the same maturity status as opposed to peers of the same chronological

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age. Interindividual differences in maturity status within the same chronological age group present a significant challenge to key stakeholders involved in the evaluation of an athlete's physical performance test such as the linear sprint test (4).

To facilitate the interpretation of linear sprint performance of adolescent athletes, it is important to develop normative data in relation to both chronological age and maturity status. A recent study computed age-specific development performance curves by calculating percentiles with selected quantiles (0.38th, 2.27th, 9.12th, 25.25th, 50th, 74.75th, 90.88th, 97.72nd, and 99.62nd) for 10- and 40-m sprint performance in elite youth outfield soccer players from the Middle East relative to chronological age (21). However, reference centiles were only fitted by using chronological age, thus not considering biological maturity when developing the reference centiles. Similarly, reference centiles for various physical performance characteristics (strength, power, endurance, and flexibility) in relation to chronological age were computed in male youth soccer players aged 9–19 years (18,46), and elite female youth and senior soccer players aged 12.7–36 years (11). To date, there are no studies that computed reference centiles for chronological age and biological maturity separately in male youth soccer player. This is crucial as it provides individual chronological and biological maturity sprint performance scores and in turn a more maturity-sensitive strategy for assessing and evaluating current physical performance (49).

Therefore, the aim of the current study was to compute reference centiles for linear sprint performance (5- and 30-m split times) as critical physical performance indicator in soccer relative to chronological age and maturity status relevant to highly trained youth soccer players. A secondary aim was to evaluate the impact of maturity status on sprint performance by comparing the individual's sprint performance scores derived from the chronological age and maturity reference centiles. Since advanced biological maturity status is, on average, associated with better sprint performance, we hypothesized that athletes advanced in biological maturity will present poorer performance scores when sprint times are expressed relative to biological maturity reference centiles, while the opposite will be evident for athletes delayed in biological maturity. The results of this study will provide objective reference data for practitioners to better interpret the sprint performance of their respective athletes in relation to both chronological and skeletal age facilitating the decision-making process for talent identification, selection, and development purposes.

Methods

Participants

The study sample included sprint performance assessments data available for a sample of N = 452 male academy soccer players and n = 1745 data points for 5 and 30 m, respectively (chronological age range: 9.4–19.3 y), over a 7-year period (summer 2016 to autumn 2023). Skeletal age data were available for a subsample of N = 295 players and n = 824 data points (chronological age range: 9.4–17.4 y, skeletal age range: 8.5–18.2 y, difference skeletal minus chronological age range: −2.1 to +4.6 y, standing height range: 133.0–191.1 cm, body mass range: 28.3–89.2 kg) over a 4-year period (autumn 2019 to autumn 2023). Prior to this period, biological maturity was not systematically estimated or measured; therefore, it was not possible to incorporate additional biological maturity data prior to autumn 2019. Players were registered for the U11 to U19 age groups (ie, U11, U12, U13, U14, U15, U16, U17, and U19) of a professional German Bundesliga club. Players can be classified as tier 3 athletes, that is, highly trained, according to the Participant Classification Framework (30). Data were collected as part of the routine player monitoring procedures of the youth academy so that ethical approval was not required (50). Upon enrollment 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

The current investigation followed a retrospective, mixed-longitudinal study approach, whereby the number of measurements per player varied from 1 to 15 across the study period. Sprint performance was measured using a 30-m linear sprint test 2 times at approximately the middle of the first and second half of the competitive season as part of the physical performance testing battery. Biological maturity was determined by measuring skeletal age within a time interval of 4 weeks prior to or after the 30-m sprint test. Standing height (±0.1 cm) was measured using a wall-mounted stadiometer (seca 206, seca), and body mass (±0.1 kg) was measured using digital scales (Kern MPE-E, KERN & SOHN GmbH) according to the guidelines of International Society for the Advancement of Kinanthropometry as part of the skeletal age assessment. All assessments were conducted at the same time of the day between 5 and 7 PM to reduce the effect of circadian rhythm upon anthropometric measurements and physical performance (40,48).

Procedures

Sprint Performance Assessment

After a 15-minute warm-up consisting of jogging, sprint-specific drills, and short accelerations, players performed three 30-m sprints separated by at least 60 seconds of recovery between each trial. Split times at 5, 10, 20, and 30 m were recorded. Five- and 30-m split times were selected for subsequent analysis as repeated-measures correlation analysis showed that the correlation coefficient was smaller for the 5- and 30-m split times ($r = .62$; 95% CI, 0.56 to 0.67) compared with the 10 and 30 m ($r = .83$; 95% CI, 0.81 to 0.86). Dual-beam timing gates (Sportronic) were used with times measured to the nearest 0.01 second. Timing gates were mounted at a height of 0.95 m and the starting distance from the first timing gate was set at 0.30 m. Players were instructed to perform a split-stance standing start for all trials and sprint as fast as possible over the full 30 m distance. Split times from the best 30-m sprint performance were used for subsequent analyses.

Skeletal Age as Indicator of Biological Maturity

Assessment of skeletal age was performed with the U11 to U17 age groups. Skeletal age was determined using the BAUSport system (SonicBone Medical Ltd) by measuring bone density at 3 sites of the left hand: wrist, metacarpals, and third phalanx. Details of the method are described elsewhere (43). Skeletal age was automatically computed by the proprietary software based on the scoring method of Tanner-Whitehouse II method (47) with a maximum skeletal age of 18.2 years (22). Assessments were performed by 2 trained examiners (Ruf and Kloss). Interrater reliability of the skeletal age assessment was calculated for a subsample of 17 players. The mean difference between both examiners was 0.10 years (95% CI, 0.01 to 0.20 y). Intrarater reliability for each of the 3 sites was initially established from a sample of 39 measurements for one of the examiners (Ruf) (43). Players were classified based on the difference between skeletal age and chronological age to provide an indicator of relative maturity, whereby a skeletal age of ≤ −1.0 years than chronological age was defined as late maturity status (n = 35 data points), a skeletal age within ±1.0 years of chronological age was defined as on-time maturity status (n = 388 data points), a skeletal age of ≥1.0 and <2.0 years than chronological age was defined as early maturity status (n = 229 data points), and a skeletal age of ≥ 2.0 years than chronological age was defined as very early maturity status (n = 96 data points) (22). Previous research informed the adoption of relative skeletal maturity categories with a band width of ±1.0 year to classify players into distinct groups (27). In addition, the band of ±1.0 year approximated SDs of skeletal age within single-year chronological groups of boys aged 5–17 years in both general and athletic populations (24). Given the overrepresentation of early maturing players in our sample, we decided to create an additional group of very early maturity status (ie, skeletal age of ≥2.0 y than chronological age) following the rationale as described above.

Statistical Analyses

Descriptive statistics are presented as mean (SD) or 95% CIs. Reference centiles for 5 and 30 m were fitted using the gamlss package (41). Reference centiles for the chronological age reference curves were fitted using data from the U11 to U19 age groups (N = 433 players, n = 1745 data points, fitted age range: 10.5–19.0 y), while skeletal age reference curves were fitted using data from the U11 to U17 age groups (N = 272 players, n = 776 data points, fitted age range: 10.5–18.2 y). All continuous distributions available within the gamlss package were fitted for the criterion variables 5 and 30 m for both chronological and skeletal age data sets with a penalty of $k = 2$ and the distribution with the lowest Generalized Akaike Information Criterion selected for each model. Smoothness of each model was controlled by using nonparametric penalized P-splines (12) for mu, sigma, nu, and tau for the predictor variables chronological and skeletal age. The Rigby and Stasinopoulos algorithm was selected for fitting mean and dispersion as it does not require accurate starting values for mu, sigma, nu, and tau to ensure convergence. Detailed information for each model can be found in the Supplementary Table S1 (see Supplementary Material [available online]). Visual inspection of worm plots was performed as model diagnostics tool in the Supplementary Figure S1 (see Supplementary Material [available online]) (6). Subsequently, chronological and skeletal age reference centiles with selected quantiles (0.38th, 2.27th, 9.12th, 25.25th, 50th, 74.75th, 90.88th, 97.72nd, and 99.62nd) were derived for 5 and 30 m based on the fitted models (8). Additionally, chronological and skeletal age z scores were computed for the individual 5- and 30-m sprint time values given the chronological or skeletal age values at the time of observation (using the *centiles.pred* function). Linear mixed-effects models (*lme4* package [3]) assessed the differences between chronological and skeletal age z scores (chronological minus skeletal) for 5 and 30 m for each maturity group (ie, late, on-time, early, very early). Random effects were fit by specifying a random intercept for individual player ID. z scores between chronological and skeletal age performance curves were specified as fixed factor (ie, categorial factor with 2 levels). Statistical significance was assessed using the Satterthwaite's degrees of freedom method (*lmerTest* package [20]) with statistical significance set at $P < .05$. Subsequently, standardized mean differences (SMD, based on Cohen d's effect size principle using the pooled SD) were calculated based on the estimated marginal means using the *emmeans* package (44) derived from the linear mixed-effects models and presented with 95% CIs. Threshold values for SMD were as follows: ≤0.2 (trivial), >0.2 to 0.6 (small), >0.6 to 1.2 (moderate), and > 1.2 (large). Analyses were performed with Rstudio (version 1.3.1056, R Foundation for Statistical Computing).

Results

Descriptive statistics for chronological age, skeletal age, and 5- and 30-m sprint performance relative to age groups U11 to U19 are summarized in Table 1. Reference centiles with selected quantiles (0.38th, 2.27th, 9.12th, 25.25th, 50th, 74.75th, 90.88th, 97.72nd, and 99.62nd) for the chronological and skeletal age for 5-m sprint performance are shown in Figure 1 and for 30-m sprint performance are shown in Figure 2. For the 5-m chronological age and skeletal age reference centiles, the Box-Cox Cole Green original distribution was used. For the 30-m chronological age reference centiles, the power exponential distribution was used, while for the 30-m skeletal age reference centiles, the Box-Cox power exponential original distribution was used.

Visually, the reference centiles based on the chronological age increased more rapidly from the age of 10.5–15.5 years and leveled off thereafter. In contrast, reference centiles based on the skeletal age increased most rapidly between the age of 13.0 and 16.5 years and leveled off thereafter. Detailed information about the chronological and skeletal percentile values for both 5- and 30-m sprint performance can be found in the Supplementary Tables S2–S5 (see Supplementary Material [available online]).

Individual z scores for 5- and 30-m sprint performance relative to chronological and skeletal age for each maturity group (ie, late, on-time, early, very early) are shown in Figures 3 and 4, respectively. A negative difference indicates that the individual

Table 1 Descriptive Statistics (Mean [SD]) for Chronological Age, Skeletal Age, 5- and 30-m Sprint Performance Relative to Age Groups U11 to U19

Variable	U11	U12	U13	U14	U15	U16	U17	U19
Chronological age, y	10.9 (0.2)	11.6 (0.4)	12.6 (0.4)	13.6 (0.4)	14.6 (0.4)	15.5 (0.4)	16.5 (0.5)	17.9 (0.6)
Skeletal age, y	11.7 (0.6)	12.1 (0.9)	12.9 (1.0)	14.5 (1.3)	15.7 (1.2)	16.7 (1.0)	17.2 (0.8)	na
Standing height, cm	147.6 (4.5)	149.9 (5.6)	154.9 (7.0)	164.4 (8.2)	171.4 (7.2)	175.9 (6.4)	178.6 (6.2)	na
Body mass, kg	37.2 (3.8)	39.2 (5.1)	43.1 (6.2)	52.5 (9.6)	60.7 (9.9)	66.4 (7.3)	70.5 (6.0)	na
5 m, s	1.21 (0.07)	1.17 (0.06)	1.15 (0.06)	1.12 (0.07)	1.08 (0.05)	1.05 (0.05)	1.04 (0.05)	1.03 (0.04)
30 m, s	5.15 (0.20)	4.82 (0.20)	4.74 (0.19)	4.55 (0.23)	4.32 (0.17)	4.20 (0.13)	4.11 (0.13)	4.08 (0.11)

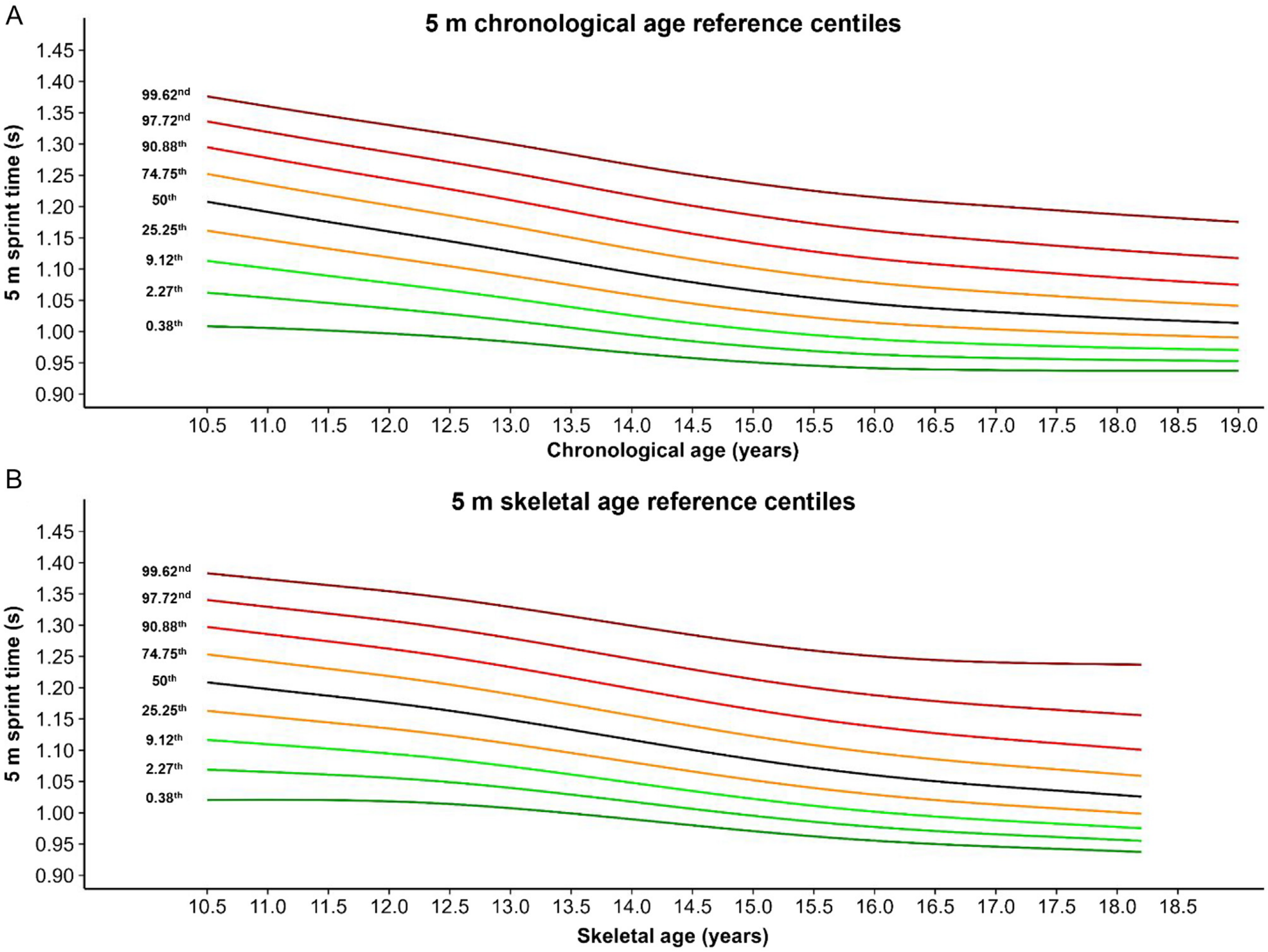

Figure 1 — Reference centiles with selected quantiles (0.38th, 2.27th, 9.12th, 25.25th, 50th, 74.75th, 90.88th, 97.72nd, and 99.62nd) for 5-m sprint performance for both chronological (panel A) and skeletal age (panel B).

chronological z scores were better than the individual skeletal z scores, that is, an athlete had a better sprint performance within the chronological reference centiles compared with the skeletal age reference centiles. For the 5-m split time, differences in individual chronological and skeletal age z scores were small for very early (SMD = –0.43; 95% CI, –0.72 to –0.14) and late (SMD = 0.58; 95% CI, 0.10 to 1.06) as well as trivial for early (SMD = –0.19; 95% CI, –0.37 to –0.01) and on-time (SMD = 0.16; 95% CI, 0.02 to 0.30) maturing players (see Figure 3). For the 30-m split time, differences in individual chronological and skeletal age z scores were moderate for very early (SMD = –0.73; 95% CI, –1.02 to –0.43), small for early (SMD = –0.30; 95% CI, –0.48 to –0.11) and on-time (SMD = 0.28; 95% CI, 0.13 to 0.42), and large for late (SMD = 1.29; 95% CI, 0.77 to 1.80) maturing players (see Figure 4).

Discussion

The assessment of sprint performance is a standard procedure within youth soccer academies relevant to the understanding of the current and potential future physical performance. In this context, we computed reference centiles for the 30-m sprint test relative to chronological and skeletal age in highly trained youth soccer players. Subsequently, we compared the individual's sprint performance scores relative with the chronological and biological reference centiles in order to evaluate the impact of biological maturity upon sprint performance. The main findings of our retrospective, mixed-longitudinal study revealed that (1) the shape of the chronological and skeletal age reference centiles differed markedly, and (2) both 5- and 30-m sprint performance showed small to moderate reductions for very early maturing players but moderate to large improvements for late maturing players when expressed relative to skeletal age compared with chronological age reference centiles. Our data substantiate the notion that sprint performance needs to be contextualized relative to the current maturity status to avoid misevaluating of the current and potential future physical performance of youth soccer players.

A number of factors pose challenges in evaluating cross-sectional and longitudinal measurements of linear sprint performance in youth soccer academies. One factor that needs to be considered when interpreting sprint times of youth soccer players is the maturity status (eg, skeletal age at the time of observation) (35). It is well established that youth athletes of the same chronological age group vary substantially in skeletal age, particularly in the age groups U12 to U16 (see Table 1) (27,43). Consequently, the shape of the chronological and skeletal age reference centiles differed markedly for both 5 and 30 m. For the chronological age reference centiles, sprint performance improves steadily up to the age of approximately 15.5 years given the heterogenous, but, on average,

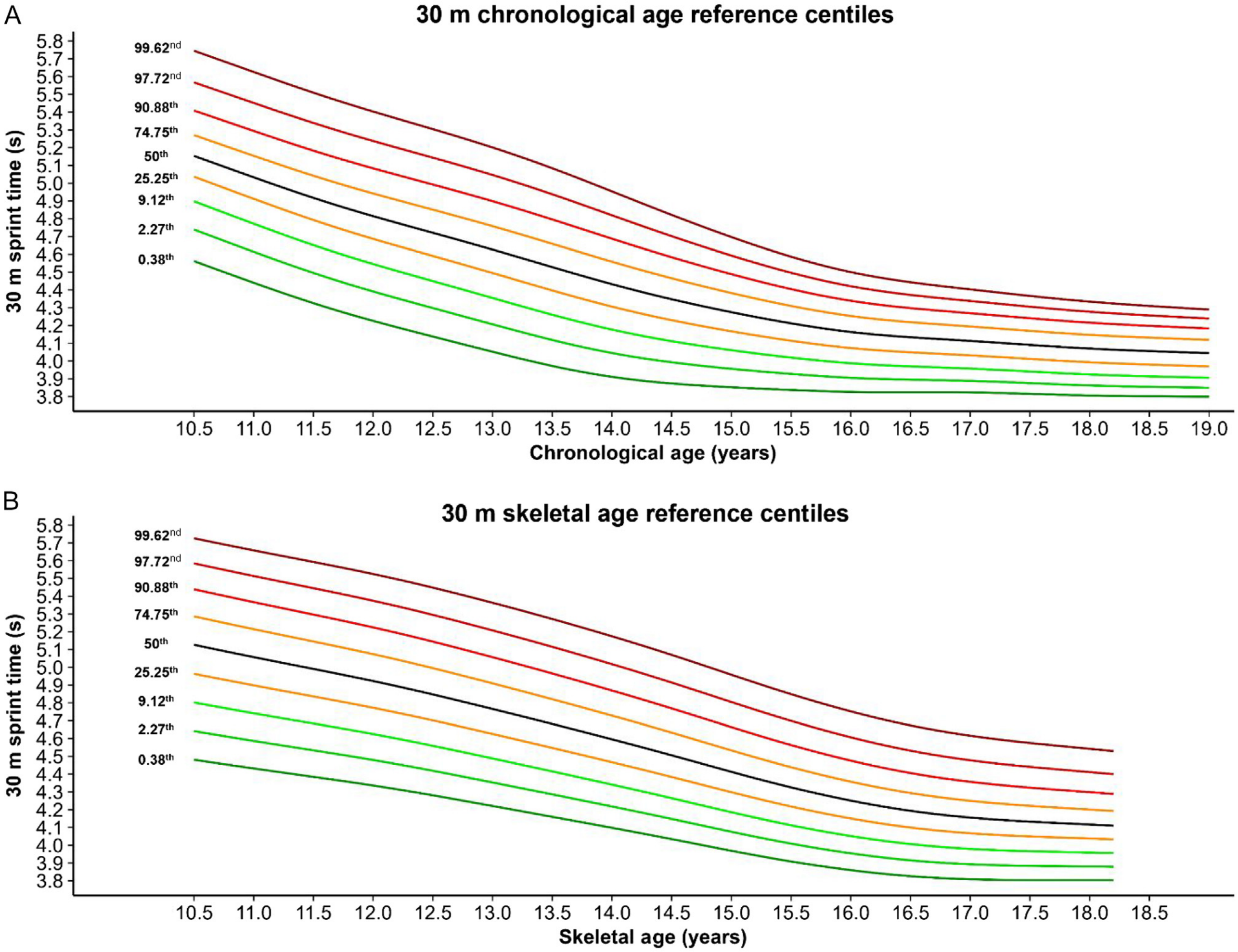

Figure 2 — Reference centiles with selected quantiles (0.38th, 2.27th, 9.12th, 25.25th, 50th, 74.75th, 90.88th, 97.72nd, and 99.62nd) for 30-m sprint performance for both chronological (panel A) and skeletal age (panel B).

biologically early maturing sample. Conversely and as expected, sprint performance of the skeletal age reference centiles improved only slightly up the age of 13.0 years (preadolescent growth spurt), followed by a more pronounced improvement up to the age of 15.5 years (adolescent growth spurt) (32). Following the age of 15.5 years, both reference centiles leveled off as chronological age approaches the skeletal age (postadolescent growth spurt). As such, from a practical perspective, our reference centiles for 5 and 30 m (see Figures 1 and 2) with selected quantiles provide a valuable tool for practitioners to make better informed and contextualized decisions about the individual sprint performance of youth soccer players for talent selection and development purposes.

In line with our hypotheses, athletes advanced (ie, very early maturing) in biological maturity presented poorer performance scores when sprint times were expressed relative to biological maturity reference centiles. Conversely, athletes delayed (ie, late maturing) presented better performance scores when sprint times were expressed relative to biological maturity reference centiles. Effects were somewhat more pronounced for 30-m sprint times than for 5-m sprint times (see Figures 3 and 4). Similar findings were reported for 5-m sprint performance in male youth tennis players with 89% of early maturing males (assessed using the percentage of predicted adult height method following the Khamis–Roche protocol [19]) moving out of the top 10% when percentiles were expressed relative to biological maturity rather than chronological age developmental curves (35).

The (transient) athletic advantages for biologically early maturing athletes compared with their biologically less mature counterparts in physical performance such as linear sprint performance are well documented (4,37). With the onset of the adolescent growth spurt, youth athletes increase sprint performance more rapidly primarily as a result of increased force-producing capabilities due to a rise of testosterone levels and musculotendon properties. This has been shown in studies with untrained and trained youth athletes following cross-sectional (31,36) and longitudinal study designs (37). Thus, biologically late maturing athletes are less physically developed compared with biologically more mature athletes of similar chronological age, and in turn, sprint performance is poorer when expressed relative to chronological age reference centiles. Biologically very early maturing athletes likely possess a lower training age and in turn are physically less developed despite their advanced biological maturity compared with chronologically older athletes of similar biological maturity. As such, performance scores are, on average, poorer when compared with athletes of similar skeletal age, but from different age groups and thus chronological ages (eg, U15 player: chronological age of 14.5 y, skeletal age of 17.0 y, +2.5 y, very early vs U17 player: chronological age of 16.5 y, skeletal age of 17.0 y, +0.5 y,

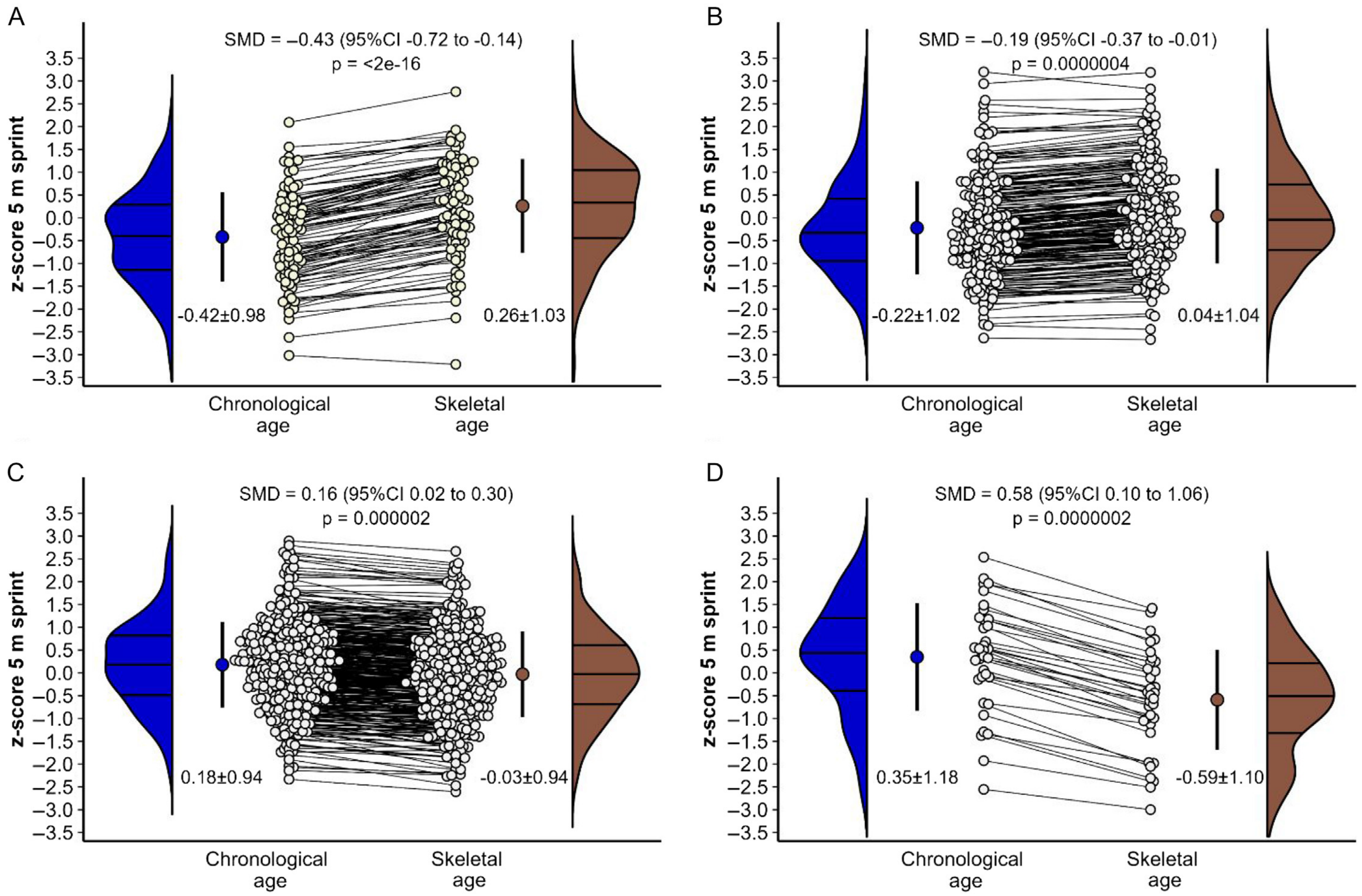

Figure 3 — Mean (SD) and individual *z* scores for 5-m sprint performance relative to chronological and skeletal age for very early (≥2.0 y, panel A, n = 96 data points), early, (≥1.0 and < 2.0 y, panel B, n = 229 data points), on-time (≥−1.0 and < 1.0 y, panel C, n = 388 data points), and late maturing players (≤−1.0 y, panel D, n = 35 data points). CI indicates confidence interval; SMD, standardized mean difference.

on-time). Of note, training age and other moderating factors such as individual genetic heritage were not measured and modeled, but likely confound our findings (17,38). Nevertheless, our findings highlight the importance of contextualizing linear sprint performance for adolescent athletes in relation to their chronological age and biological maturity at the time of observation.

We computed for the first time reference centiles relative to both chronological and skeletal age using a large sample of highly trained youth soccer players. Despite the practical applications of our findings of providing a means to evaluate an athlete's linear sprint performance relative to his chronological and skeletal age by plotting the individual sprint data on the reference centiles, several methodological considerations need to be acknowledged. Data for our investigation were derived from a single academy of a professional German soccer club. Accordingly, the reference centiles potentially reflect the academies strategy to select and develop players with certain physical profiles and are therefore not directly transferable to other clubs following different talent selection and development strategies. Thus, the development of reference centiles for linear sprint performance from youth soccer players of other countries is warranted to allow for comparisons between different populations. Likewise, sprint times are affected by the implemented protocol of the linear sprint test (ie, timing technology, starting position, footwear, running surface, starting distance) (2,16). Thus, sprint times derived through other sprint protocols cannot be used interchangeably to the sprint times presented in our investigation. Classifying athletes as early, on-time, and late based on the difference between skeletal age and chronological age is routinely performed by researcher and practitioners to express the advancement or delay in skeletal maturity or to group athletes of similar skeletal maturity (25). Although we measured skeletal age using a novel ultrasound-based device which recently has been compared against gold-standard radiographs using the Fels protocol, greater limits of agreement between both methods resulting in overestimation or underestimation of skeletal age should be noted (10). Subtle differences in marking of anatomical sites and positioning of the hand at one of the 3 sites might result in greater discrepancies in the skeletal age estimation given the lower number of estimations compared with other protocols such as Fels. Nevertheless, BAUSport provided comparable estimates of skeletal age in the sample of young athletes compared with the Fels protocol (10) and offers the advantage to noninvasively measure skeletal age without the associated limitations of standard radiographs (ie, exposure to radiation, expenses, logistical difficulties). Additionally, we acknowledge that the measurement of skeletal age through standard radiographs or the BAUSport system is currently out of reach for many soccer academies limiting the wider application of the skeletal age reference centiles. However, to apply our

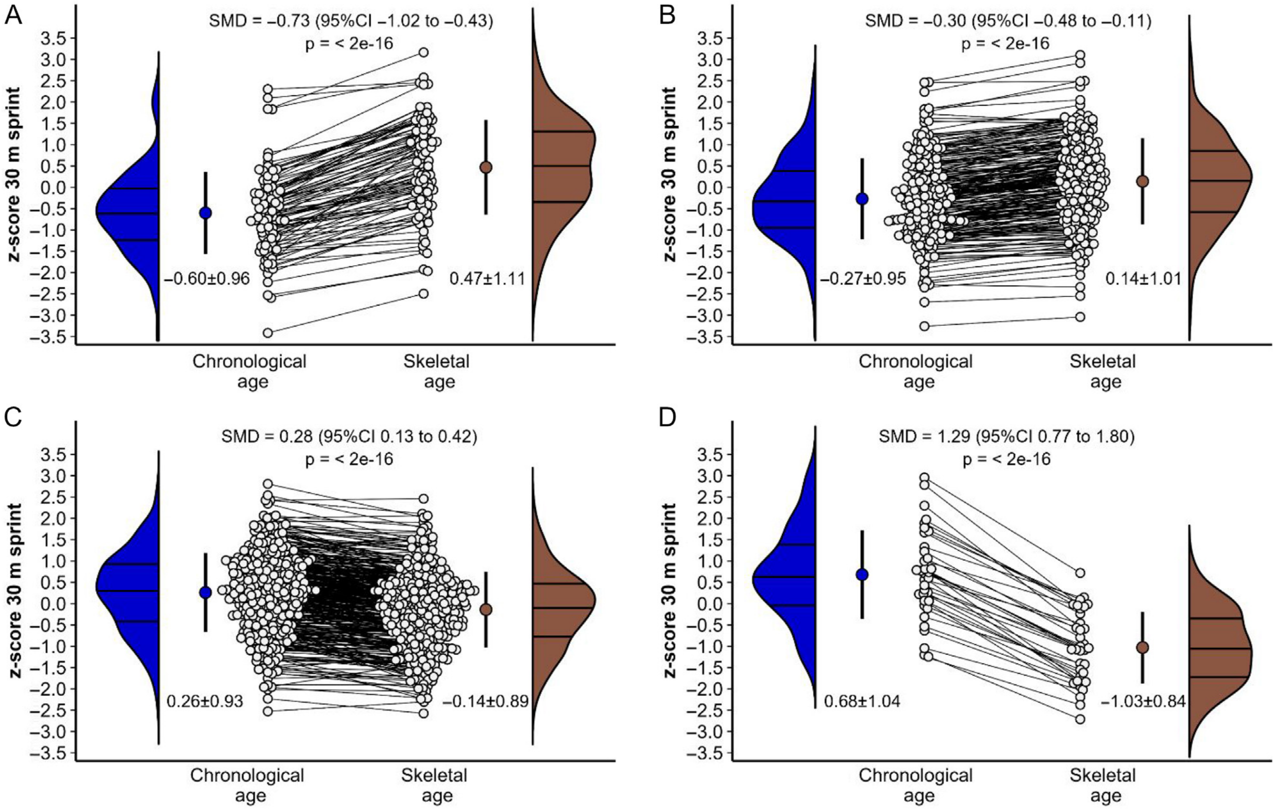

Figure 4 — Mean (SD) and individual *z* scores for 30-m sprint performance relative to chronological and skeletal age for very early (≥2.0 y, panel A, n = 96 data points), early, (≥1.0 and < 2.0 y, panel B, n = 229 data points), on-time (≥–1.0 and < 1.0 y, panel C, n = 388 data points), and late maturing players (≤–1.0 y, panel D, n = 35 data points). CI indicates confidence interval; SMD, standardized mean difference.

approach practitioners might consider converting the somatic maturity indicator percentage of predicted adult height into an index of maturity status, labeled biological age, by using country-, age- and sex-specific growth data as previously outlined (35,43). The lack of a consensus on classification criteria and definitions and the shortcomings of converting a continuous variable such as skeletal age into categories and the lack of accounting for the reliability of the skeletal age assessment within the groupings likely contributed to potential misclassifications of athletes and loss of residual confounding (1,42). Finally, the composition of our sample requires consideration. Given the constraints of applied research within high-performance environments, we used a retrospective, mixed-longitudinal study approach to estimate chronological and skeletal age-specific reference centiles. Although the precision and accuracy of centile estimations is likely slightly compromised for a mixed-longitudinal approach, it addresses cost-related limitations associated with cross-sectional and longitudinal study designs (ie, recruitment and retention of athletes) and therefore is a viable alternative to develop age-specific reference centiles (9). Nevertheless, our approach limits us in calculating precise CIs around each reference centile across the chronological and skeletal age range (7).

Conclusion

This study provides reference centiles for the 30-m sprint test including its split time of 5 m relative to chronological and skeletal age in highly trained youth soccer players. Outcomes from the comparisons between individual's chronological and skeletal age sprint performance scores highlighted the importance to contextualize the current sprint performance relative to the biological maturity status. When expressed relative to skeletal age reference centiles, sprint performance showed small to moderate reductions for very early maturing players and moderate to large improvements for late maturing players in this population. These findings provide a practical means to evaluating sprint performance in relation to biological maturity status in highly trained youth soccer players.

Acknowledgments

Data Availability Statement: Due to the policy of the participants club data cannot be shared and, therefore, are not available publicly. The data that support the findings of this study are available on request from the corresponding author.

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