Journal of Science and Medicine in Sport xxx (xxxx) xxx

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

# Differences in physical and technical performance characteristics between 11v11 chronological and bio-banded soccer match-play format in youth soccer

J. Salter [a,*], D. Forsdyke [a], L. Arenas [b], Z. Dawson [a], M. King [c], N. Myhill [d], J. Robinson [e], C. Towlson [e], M. Springham [f], L. Walsh [a], S. Mallinson-Howard [a,h], S. Barrett [g]

[a] InSPIRe, School of Science, Technology & Health, York St John University, UK
[b] Institute of Sport and Preventative Medicine, Saarland University, Germany
[c] School of Cardiovascular and Metabolic Health, University of Glasgow, UK
[d] Carnegie School of Sport, Leeds Beckett University, UK
[e] School of Sport, Exercise and Rehabilitation Science, University of Hull, UK
[f] Faculty of Sport, Allied Health and Performance Science, St Mary's University, UK
[g] Playermaker, UK
[h] MPaW, Science, Technology and Health, York St John University, UK

ARTICLE INFO

*Article history:*
Received 28 April 2025
Received in revised form 22 August 2025
Accepted 15 September 2025
Available online xxxx

*Keywords:*
Bio-banding
Growth
Maturation
Physical demands
Technical demands

ABSTRACT

*Objectives:* Bio-banding groups athletes by maturity rather than chronological age, to promote more equitable competition and development opportunities. We investigated whether physical and technical performance differed between chronological and bio-banded 11v11 match-play formats in youth soccer. A secondary aim was to examine whether these differences varied by maturity status and timing.
*Design:* Twelve Junior Premier League teams ($N = 139$ players) from the U13, U14, and U15 age groups participated. Each team played six, 20-minute matches: three in chronological age and three in bio-banded formats. Bio-banding was based on the percentage of predicted adult height: pre-peak height velocity (<90 %), mid-peak height velocity (90–96 %) and post-peak height velocity (>96 %).
*Methods:* Players wore foot-mounted inertial measurement units to record physical (distance covered, high-speed running >4 m/s, sprinting >5.5 m/s, and accelerations/decelerations ±2.6 m/s/s) and technical (total touches, possessions, time on ball and one-touch/short/long possession counts) performance characteristics. Data were analysed using *t*-tests and analysis of variance with Bonferroni correction. Significance was set at $p < 0.05$, and effect sizes (Cohen's $d$) were calculated. A multivariate analysis was also conducted.
*Results:* Whole sample analysis showed significantly more time on the ball per possession ($d = 0.17$), and fewer one-touch actions ($d = 0.25$) in bio-banded matches. Post-peak height velocity players covered significantly more high-intensity distance ($d = 0.63$) but recorded fewer total touches ($d = 0.60$), total possessions ($d = 0.65$) and one-touch possessions ($d = 0.71$) in the bio-banded format. There were significant differences between pre- and mid-peak height velocity players for all physical metrics across both chronological and bio-banded matches ($d = 0.48$–72), and between maturity groups (pre-post-peak height velocity, mid-post-peak height velocity) for technical actions in chronological format but not mirrored in bio-banding matches.
*Conclusions:* Bio-banding was associated with altered physical and technical demands, especially for post-peak height velocity players. Findings suggest bio-banding may provide an appropriate competition format, exposing players to different developmental challenges, which may support more equitable and balanced experiences.


## Practical implications

- **Limited Whole-Group Differences**: There were no significant overall physical differences between bio-banded and chronological formats,

* Corresponding author.
*E-mail address:* j.salter@yorksj.ac.uk (J. Salter).
*Social media:* @Jay_Salter, @jsalter.bsky.social (J. Salter).

https://doi.org/10.1016/j.jsams.2025.09.006

and only minor technical changes, suggesting that whole-group analysis may mask meaningful subgroup effects.

- **Maturity-Specific Impacts**: Bio-banding altered experiences for players depending on maturity stage—post-PHV players had reduced ball involvement but higher physical outputs, whilst pre- and mid-PHV players saw minimal changes, highlighting bio-banding's potential to re-balance development opportunities.
- **Developmental Benefits of Bio-Banding**: By levelling the playing field, bio-banding reduced dominance by early-maturing players and encouraged more technical and tactical engagement, promoting holistic development and equity across maturity levels.
- **Load Regulation Potential**: Though physical load differences by maturity stage persisted across both match types, bio-banding may help manage injury risk by enabling maturity-appropriate physical intensities, without forcing less mature players to match higher physical demands.

## 1. Introduction

Talent is a combination of an individual's innate potential for success and a product of their developmental experiences.[1] The effectiveness of talent environments relies on whether they afford individuals the opportunities to express their innate potential, whilst simultaneously nurturing the technical, tactical and psychosocial attributes necessary for progression into a high-performance senior programme.[2] To address these issues, talent development environments need to be adaptable to accommodate individuals to develop in harmony with their maturity status, timing and tempo, enabling stakeholders to make more accurate estimations of performance potential.[2,3] However, many talent development environments are structured around chronological age, with training loads (e.g., session frequency and volume) and physical expectations (i.e., speed, power, strength and aerobic capacity) increasing uniformly across age groups. This approach may not align with the biological development trajectories of all players, potentially disadvantaging late maturers and those whose development does not align with their chronological age group norms.[4] To address this misalignment, alternative grouping methods, such as bio-banding (i.e., categorising athletes by biological rather than chronological age), have gained traction. Bio-banding seeks to reduce variability in physical characteristics during competition, thereby striving to improve fairness and create opportunities that better reflect players' developmental stage.[3] The current study advances our understanding of the effects of bio-banding by examining whether physical and technical performance characteristics differ between chronological and bio-banded 11v11 match formats in youth soccer. A secondary aim is to examine whether these differences vary across maturation status and timing, both within and between bio-banded groups across the formats.

## 2. Biological maturation and bio-banding in talent development

Biological maturation refers to the progression of physical development and varies greatly among adolescents. In male athletes, it accounts for significant within-age-group variations in physical characteristics such as body mass (~50 %), stature (~17 %), percentages of predicted adult height (~15 %) and fat-free mass (~21 %).[5] These disparities are most pronounced between hr ages of 13–15 years, where a 4–6 year variation in biological age can exist.[6,7] In talent pathways, early maturers often receive greater attention due to temporary physical advantages, whilst those with relatively inferior, maturity-related physical characteristics are often prematurely deselected, particularly in sports that require strength, speed and power.[8] This inequity can result in further disadvantages, such as being channelled into certain roles and positions (e.g., a physically demanding position allocated to early maturers).[9] These issues raise important questions about the limitations of chronological age-based grouping and its potential to confound the efficacy of talent identification and development initiatives.[8,10] Consequently, there is a growing interest in alternative grouping methods that better reflect biological differences.

The concept of grouping individuals by physical attributes (i.e., size, mass or maturity) is not new and has been employed in various sports previously, including martial arts, basketball, ice hockey, handball, rugby and soccer.[6,11,12] In soccer, bio-banding, particularly for training sessions and ad-hoc competitions, has emerged as a leading alternative grouping strategy.[10,13–15] Bio-banding aims to reduce physical discrepancies between players, potentially encouraging greater technical development and tactical decision-making by limiting the overreliance on physicality often observed in chronological age-based match-play.[8,16,17]

As bio-banding gains acceptance, maturity data are increasingly being used in soccer development pathways to effectively tailor and manage training loads, reduce injury risk and address selection biases.[4,18] Accurate biological maturity assessment is key to effective implementation and can be conducted in several ways, including classification based on physical size, body mass and secondary sex characteristics, such as pubic hair development.[6,19] More recently, since the validation of non-invasive, anthropometrical-derived (e.g., somatic) methods to estimate maturity, practitioners have typically employed either the maturity offset or the percentage of predicted adult height methods.[15,20] These both offer insight into the status (%PAH) or timing (MO) of the athlete, which is used to group individuals relative to the adolescent growth spurt, commonly referred to as peak height velocity (PHV).[3] Both methods are widely utilised within male academy soccer settings,[13,14] but studies examining the precision of these methods against longitudinal growth curves suggest that %PAH offers better accuracy.[21] This is due to the genetic component included within the equation (i.e., birth parent heights), but access to this personal data is considered a primary barrier to the wider application of the method, thus resulting in many organisations preferring MO. That said, soccer practitioners who have implemented bio-banding have shown a clear preference for using the %PAH method[22] and typically grouped into pre-PHV (≤90 % PAH), mid-PHV (90–95 % PAH) and post-PHV (≥95 % PAH) groups.

To date, a limited number of studies have examined performance differences between bio-banded and chronological match formats in youth soccer. Findings related to physical performance demands (e.g., distance covered, high-speed running, and total sprints) are somewhat inconsistent with varying match formats, maturity groups, and study designs employed. For instance, Abbott et al.[23] found no significant differences in total distance, high-speed running or explosive distances covered between early, on-time or late developers in 11v11, 20-minute, bio-banded and chronological age format matches. However, they did report that late developers covered significantly greater total and explosive distances. These findings partly align with those of Lüdin et al.,[48] who reported only trivial to small differences in total and high-speed running distances between the two formats in 9v9 matches, but moderate differences ($d = 0.60$) in the number of high-intensity accelerations among early developers in bio-banded formats. Romann et al.[24] observed *small* reductions in total running distance ($d = 0.26$), jogging ($d = 0.25$), and high-speed running ($d = 0.25$) in bio-banded versus chronological matches across all participants. Adding to these findings, Arede et al.[25] reported that biologically categorised (i.e., biological age) 7v7 matches were associated with *large* reductions in distance covered ($d = 1.11$), decelerations ($d = 0.82$), average speeds ($d = 1.15$), and body impacts ($d = 0.94$), as well as *moderate* reductions in peak heart rate ($d = 0.56$). Finally, in various small-sided matches (4v4 to 6v6), King et al.[26] found that less mature players covered a higher total distance during mixed-maturity (i.e., chronological age) matches. However, when grouped by biological maturity (matched or mismatched), more mature players covered a greater high-intensity distance. When the variability across studies is coupled with limited agreement on the methods used to assess and estimate biological maturity,[27] these findings perhaps help explain the modest adoption of bio-banding in talent development environments to manage match play (6–25 %) and training loads (25–29 %).[13,14]

Compared to physical performance characteristics, bio-banding's role with respect to the technical performance of male soccer players has received more attention, though findings remained mixed. For example, Bradley et al.[28] reported that early maturers subjectively felt bio-banding afforded them greater potential to express themselves but reduced physical and technical challenges, with late maturers also feeling able to express themselves and have more influence on the match. More objectively, Romann et al.[24] reported reduced average time on the ball per possession ($d = 0.62$) in bio-banded matches, whereas Lüdin et al.[48] summarised that late-developers benefitted from greater opportunity to prove their technical skills during bio-banding due to a longer volume of time on the ball ($d = 1.25$). Abbott et al.,[23] similar to Towlson et al.,[29] reported increases in short passes across early and on-time developers, but this was possibly due to unfamiliarity with the bio-banded format, prompting simplified play. Overall, these findings suggest that whilst bio-banding is associated with altered technical engagement, the nature and direction of these effects lack clear consensus.

A key barrier to clarity in this area appears to be methodological inconsistency, including the broad range of measurement variables, estimation techniques, and data collection tools being used by researchers (e.g., maturity estimation methods, subjective perceptions of intensity, locomotor variables and physiological response [i.e., heart rate]). The emergence of validated foot-mounted isoinertial measuring units (F-IMUs; Playermaker, London, UK), now approved by the International Football Association Board (IFAB), may help in addressing this issue by presenting a more reliable, uniform, and commercially accessible means to capture both physical and technical performance (i.e., distance covered, high-speed running, technical actions) data. Further, whilst small-sided matches (i.e., 6v6, 7v7, and 9v9) seen in previous research offer useful insights into the potential of bio-banding, the transition to 11v11 match-play often occurs during the adolescent development period (i.e., 11–15 years). Given only one study has previously examined bio-banding and full match play in youth soccer[23] and there were limitations in terms of a relatively small sample size, it seems essential to replicate and extend their study with a larger and more diverse participant pool to better identify and understand any physical and technical differences between chronological and bio-banded 11v11 formats. Therefore, the current study aimed to examine the physical and technical performance characteristics of youth soccer players during 11v11 matches played under chronological and bio-banded formats, using contemporary F-IMU technology. A secondary aim was to assess how these differences vary within and between maturity status and timing groups. Based on previous research, it was hypothesised that there would likely be maturity-specific differences in physical and technical characteristics between chronological and bio-banded 11v11 formats. It was also hypothesised that bio-banding would place relatively greater physical demand on more mature (i.e., post-PHV) players and contribute to greater technical equity across maturity groups.

## 3. Materials and methods

### 3.1. Research context

To minimise the impact of day-to-day variation, drop-out and logistical complexities, this study employed a single-day design whereby soccer-specific physical and technical characteristics from multiple (i.e., six), short (20-minute) duration, 11v11 soccer matches were compared between chronological (AM) and bio-banded (PM) formats. Researchers conducted objective anthropometrical assessments (i.e., standing and seated stature and body mass) to permit estimations of maturity status during the morning of the event. This occurred whilst each team was not playing; therefore, it was not feasible to randomise chronological and bio-banded fixtures as in previous studies.[24,30] This single-day approach may have introduced potential fatigue-related confounding; however, the 20-minute format ensured no player participated in more than 120 min throughout the day to mitigate this risk. All matches were played on regular, full-size (100 × 64 m) artificial 3rd-generation, FIFA-approved soccer pitches at the same venue and refereed by Football Association-qualified officials. In chronological age-categorised matches, players represented their registered age-group team (i.e., U13, U14 or U15) and were led by their normal age-group coaches. In bio-banded matches, age groups were replaced by modified maturity categories relative to peak height velocity (PHV): pre-PHV (<90 %PAH), mid-PHV (90–96 %PAH) and post-PHV (>96 % PAH). Therefore, coaches remained within their club and on the same pitch with players who either moved up (e.g., U13 moving into mid-PHV) and were considered early maturers, down (e.g., U14 moving to pre-PHV) and considered late maturers, or remained (e.g., U15 classified as post-PHV) with the majority of their chronological cohort based on their maturity status and considered an on-time maturer. This way, players were coached by either the same or familiar coaches and represented their club but may be playing with players outside of their typical age group. Players wore F-IMUs for all matches, and comparisons of physical and technical characteristics between formats and groups were conducted.

### 3.2. Participants and ethics

Using a convenience sampling approach, 139 male soccer players aged 12–16 years who represented four separate Junior Premier League (JPL) teams were invited to participate in the event. Players registered with the U13, U14 and U15 age groups of each club were invited to participate (Table 1). These ages were selected as they include the largest biological variability and, therefore, offer the greatest utility of bio-banding.[5] Players were deemed eligible to participate if they were injury-free in the 14 days prior to the event and considered fit and healthy by their parents and coaches to attend. Following ethical approval from the (name omitted for review purposes) University Science, Technology and Health Ethics Committee (ETH2425-0017), parental consent and participant assent were obtained electronically following an online webinar by the research team to outline research objectives.

### 3.3. Measures

#### 3.3.1. Anthropometry and biological maturity

The Khamis and Roche[20] percentage of predicted adult height (% PAH) method was selected for bio-banding players. Evidence suggests that this somatic approach has greater validity compared with other commonly used somatic methods[21] and has previously demonstrated almost perfect agreement ($r = 0.96$) with contemporary developments in maturity estimation technology.[31] This approach is also the most commonly applied to categorise players when implementing bio-banding.[22] Assessment of standing stature using the Frankfort plane and stretch-stature technique (217 Stable Stadiometer, Seca, Hamburg, Germany to the nearest 0.1 cm) and body mass (Seca, Hamburg, Germany to the nearest 0.1 kg) were measured by an experienced member of the research team following published International Society for the Advancement of Kinanthropometry (ISAK) guidelines,[32] conducting a minimum of two measurements of standing stature and body mass on each player. Where significant deviations between these two readings were observed (i.e., 0.2 cm or 0.2 kg), a third measurement was conducted, and the median was selected. Due to all birth parent heights being self-reported (via the parental consent process), these were corrected for over-estimation[33] before maturity estimation equations were applied using a customised spreadsheet.[3] Where birth parent heights were not obtained ($N = 6$), the research team imputed the mean male or female parent heights from the sample. For the bio-banded matches, players were categorised using absolute % PAH thresholds (i.e., pre-PHV (<90 %), mid-PHV (90–96 %) or post-PHV (>96 %)) as opposed to a maturity or biological age offset Z-score

**Table 1**
Descriptive characteristics of chronological and bio-banded groups. Data is presented as mean ± SD and range *(in parentheses)*.

| | Height (cm) | Body mass (kg) | Leg length (cm) | PAH% | Biological age (years) | Biological age offset (years) |
|---|---|---|---|---|---|---|
| U13s | 156.4 ± 7.9 *(138.0–177.50)* | 44.9 ± 7.4 *(30.0–59.0)* | 7.1 ± 4.3 *(69.2–89.5)* | 87.7 ± 2.5 *(82.7–94.1)* | 13.1 ± 0.6 *(11.7–14.7)* | 0.29 ± 0.58 *(−0.7−1.9)* |
| U14s | 163.1 ± 8.2 *(146.0–178.8)* | 50.9 ± 8.7 *(35.6–80.0)* | 82.2 ± 4.8 *(71.8–91.0)* | 91.2 ± 2.7 *(84.8–96.8)* | 13.9 ± 0.7 *(12.3–15.6)* | 0.18 ± 0.59 *(−1.1–1.5)* |
| U15s | 172.8 ± 6.8 *(159.8–190.9)* | 58.7 ± 7.0 *(41.9–77.3)* | 87.1 ± 3.8 *(78.5–93.4)* | 96.0 ± 1.5 *(90.7–98.3)* | 15.3 ± 0.6 *(13.8–16.3)* | 0.59 ± 0.56 *(−0.9–1.5)* |
| Pre-PHV | 154.1 ± 6.2 *(138.0–169.5)* | 42.9 ± 6.1 *(30.0–57.7)* | 76.7 ± 3.4 *(69.2–81.5)* | 86.9 ± 1.7 *(82.7–90.0)* | 12.9 ± 0.4 *(11.7–13.6)* | −0.01 ± 0.53 *(−1.1–1.1)* |
| Mid-PHV | 166.3 ± 5.7 *(154.3–178.0)* | 53.9 ± 7.5 *(38.6–80.0)* | 83.9 ± 3.5 *(71.8–91.0)* | 92.6 ± 1.6 *(88.4–95.9)* | 14.3 ± 0.4 *(13.3–15.3)* | 0.44 ± 0.53 *(−0.0–1.8)* |
| Post-PHV | 176.4 ± 4.9 *(167.6–190.9)* | 60.9 ± 5.1 *(51.7–77.3)* | 89.2 ± 2.3 *(85.1–93.4)* | 97.1 ± 0.6 *(96.2–98.3)* | 15.7 ± 0.3 *(15.3–16.3)* | 0.92 ± 0.35 *(0.2–1.5)* |

(i.e., conservative [±1 year] or less conservative [±0.5 years] thresholds). These modified thresholds differ slightly from those reported previously[10,23,28] but were selected pragmatically to facilitate the numerical and positional needs of teams based on the biological distribution in the sample. Table 1 illustrates the utility of this approach to reduce the heterogeneity within groups, demonstrated by the reduced range in anthropometric measures between chronological and bio-banded groupings. Typically, PHV in boys occurs at approximately 91–92 %PAH (~13.8 years), which would occur during the U14 season.[6,34] Therefore, this was considered 'typical' timing, with most players (78.2 %) aligning with this (on time), 10.2 % considered early (moved up) and 11.5 % considered late developers (moved down) for the bio-banded format.

*3.3.2. Foot mounted isoinertial measuring units (F-IMUs)*

Physical and technical characteristics were quantified using F-IMUs (Playermaker, London, UK), with a glossary of metrics used provided in Supplementary Table 1. These units have previously been deemed valid and reliable across various populations.[35,36] Each player wore devices located at the lateral malleoli of each foot that incorporated a 16g triaxial accelerometer and 2000°/s$^{-1}$ triaxial gyroscope housed within manufacturer-provided, tight-fitting silicone bootstraps (Fig. 1). Activities were initiated via Bluetooth connection to iPads for each pitch (Apple Inc., California) and uploaded to the manufacturer's cloud-based software (v3.22.0.02) via Wi-Fi following the morning (chronological) and afternoon (bio-banded) matches.

*3.3.3. Physical characteristics*

A range of youth-specific absolute (total distance [m], high-intensity distance [m > 4 m/s], sprint count [#], sprint distance [m > 5.5 m/s], top speed [m/s] and intense speed change accelerations and decelerations [# > 2.6 m/s/s]) and relative (work rate [m/min], high-intensity work rate [m/min > 4 m/s], sprint work rate [m/min > 5.5 m/s] and intense speed change accelerations and decelerations [#/min > 2.6 m/s/s] physical locomotor actions were collected in both match formats. All metrics demonstrate *good* to *excellent* between-unit reliability (intraclass correlation coefficients 0.89–0.96) in football-specific locomotive tasks.[36] These physical metrics were selected for two primary reasons: i) evidence suggests incremental improvements in physical characteristics across maturation, particularly in high-intensity attributes (e.g., sprinting, high-speed running and agility), and ii) these metrics align with those reported in previous studies, including male youth soccer players.[26]

*3.3.4. Technical characteristics*

Total touches (#) of the ball and the rate of these touches (#/min) on the left (#) and the right (#) foot were assessed using the F-IMU devices. The total number of possessions (#) was further divided into short (<1.5 s; #), long (>1.5 s; #) and one-touch (#) possessions, with average times on the ball provided for both short and long possessions (s). Finally, the total time on the ball (s) and average time per possession (s) were collected for all players across both match formats. As above, these technical metrics demonstrate excellent reliability (95.9–96.9 % proportion of agreement)[35] and were selected due to i) previous evidence suggesting interactions between age and/or maturity and technical characteristics,[24,29,30] and ii) similar characteristics being reported in male youth soccer populations.[37]

*3.4. Data analysis*

Before analysis, data were visually screened for normal distribution using Q–Q plots. All data is presented per player per 20-minute game as mean ± standard deviation (mean ± SD). This resulted in 615 individual player observations across both chronological ($N = 327$) and bio-banded ($N = 288$) formats. Injury and/or missing maturity data for a small number of players ($N = 7$) explain fewer observations in the bio-banding format. Partial least squares correlation analysis (PLSCA) was used to identify the relationships between the sets of variables (physical and technical characteristics) and explore which, if any, possessed the most relative importance to discriminate between formats.[38] A leave-one-variable-out approach was conducted to identify the change in inertia when each locomotor variable was omitted.[38,39] The count data were log-transformed to reduce skewness before analysis. The variables deemed to possess relative importance were determined by a visual break (i.e., the 'elbow') within the decrease in the singular value inertia plot (Supplementary Fig. 1).


**Fig. 1.** Visual representation of the F-IMU silicone strap (left panel) and how this sits when mounted on the player's boot (right panel).

Following the multivariate analysis, dependent *t*-tests and Cohen's *d*-effect sizes (JASP, v0.19.3, Intel, Amsterdam) were used to determine whole-sample and within-group (i.e., status and timing) statistical and magnitude of mean differences between match formats. Secondly, analysis for between-maturity group differences (i.e., maturity status) used analysis of variance (ANOVA). Bonferroni corrected thresholds for statistical significance were set at $p \leq 0.05$, alongside 95 % confidence intervals (95 % CIs) and thresholds for interpreting effect size difference magnitudes (Cohen's $d$) adhered to published norms, <0.2 (*trivial*), 0.2 (*small*), 0.5 (*moderate*), and 0.8 (*large*).[40]

## 4. Results

### 4.1. Within-group differences

Supplementary Fig. 1 describes the relative variable importance of discriminating between formats derived from the PLSCA. The baseline singular value inertia (i.e. the calculated inertia with all the predictor variables included in the model) was low for physical (60.5) and technical characteristics (78.4, 41.3), indicating a generally weak relationship between all variables and match format. Therefore, there were no dominant variables, and all variables were included for analysis. The findings of the whole sample analysis (Table 2) demonstrated that bio-banded match-play led to significantly ($p = 0.002$) fewer one-touch actions (1.2 ± 0.4, $d = 0.20$) and significantly ($p = 0.040$) more time on the ball per possession (0.12 ± 0.1, $d = 0.17$). There were no other whole sample significant differences ($p = 0.059$–$0.085$) for physical or technical characteristics across the match formats. However, within-group analysis of maturity status (Table 3) identified that post-PHV players covered significantly more high-intensity distance (83.8 ± 26.3, $d = 0.63$) and had fewer total touches (10.6 ± 3.5, $d = 0.60$), touches per minute (0.6 ± 0.2, $d = 0.67$), right foot touches (8.9 ± 2.9, $d = 0.61$), total possessions (4.5 ± 1.3, $d = 0.65$) and one-touch possessions (3.4 ± 0.9, $d = 0.71$) in bio-banded matches. There were no significant differences ($p = 0.817$–$1.000$) between physical and technical characteristics for pre-PHV and mid-PHV players between the two formats. Additionally, there were no significant ($p = 1.000$) performance differences for early, on-time or late maturers between chronological and bio-banded formats (Table 4).

**Table 2**
Physical and technical characteristics between chronological and bio-banded formats. Data presented are averages per 20-minute match.

| Metric | Chronological (mean + SD) (N = 327) | Bio-banded (mean ± SD) (N = 288) | Mean diff ± SD (95 % CI) | *p*-Value Effect size (*d*; *inference*) |
|---|---|---|---|---|
| *Physical characteristics* | | | | |
| Distance covered (m) | 1796.7 ± 444.3 | 1842.4 ± 476.8 | 46.6 ± 37.1 (−119.6 to 28.2) | 0.209 *0.10*; *trivial* |
| Work rate (m/min) | 89.3 ± 21.9 | 86.5 ± 22.9 | 2.8 ± 1.8 (−0.7 to 6.3) | 0.119 *0.12*; *trivial* |
| High intensity work rate (m/min) | 10.8 ± 6.6 | 10.9 ± 7.0 | 0.1 ± 0.5 (−1.2 to 0.9) | 0.852 *0.02*; *trivial* |
| Sprint work rate (m/min) | 1.3 ± 1.6 | 1.4 ± 1.8 | 0.1 ± 0.1 (−0.4 to 0.1) | 0.349 *0.07*; *trivial* |
| Sprint count (#) | 3.9 ± 3.9 | 4.1 ± 4.4 | 0.1 ± 0.3 (−0.8 to 0.5) | 0.654 *0.04*; *trivial* |
| Top speed (m/s) | 5.9 ± 0.8 | 5.9 ± 0.8 | 0.0 ± 0.1 (−0.1 to 0.1) | 0.559 *0.05*; *trivial* |
| HID covered (m) zone 1 [>4 (m/s)] | 218.4 ± 133 | 231.2 ± 144 | 13.1 ± 11.2 (−35.2 to 8.8) | 0.240 *0.01*; *trivial* |
| SD covered (m) [>5.5 (m/s)] | 26.1 ± 33.4 | 29.7 ± 36.5 | 3.7 ± 2.8 (−9.2 to 1.8) | 0.190 *0.10*; *trivial* |
| Intense speed changes acc/decl actions (#) [>2.6 ($m/s^2$)] | 12.4 ± 8.1 | 11.9 ± 8.6 | 0.4 ± 0.6 (−0.9 to 1.7) | 0.491 *0.05*; *trivial* |
| Intense speed changes acc/decl actions per min (#/min) | 0.6 ± 0.4 | 0.5 ± 0.4 | 0.1 ± 0.1 (−0.0 to 0.1) | 0.119 *0.12*; *trivial* |
| *Technical characteristics* | | | | |
| Total touches (#) | 25.1 ± 20.1 | 23.7 ± 15.3 | 1.33 ± 1.4 (−1.4 to 4.1) | 0.359 *0.07*; *trivial* |
| Touches per min (#/min) | 1.24 ± 1.0 | 1.11 ± 0.7 | 0.13 ± 0.1 (−0.0 to 2.7) | 0.059 *0.15*; *trivial* |
| Left foot touches (#) | 7.9 ± 10.4 | 7.5 ± 8.8 | 0.45 ± 0.8 (−1.1 to 2.0) | 0.561 *0.04*; *trivial* |
| Right foot touches (#) | 17.1 ± 15.8 | 16.2 ± 13.5 | 0.87 ± 1.2 (−1.4 to 3.2) | 0.465 *0.06*; *trivial* |
| Total possessions (#) | 9.8 ± 8.1 | 8.8 ± 5.5 | 0.96 ± 0.5 (−0.1 to 2.0) | 0.091 *0.13*; *trivial* |
| Short possessions (#) | 1.9 ± 2.1 | 1.9 ± 1.9 | 0.06 ± 0.1 (−0.3 to 0.4) | 0.721 *0.03*; *trivial* |
| Average time on the ball – short possessions (s) | 1.0 ± 0.2 | 1.0 ± 0.2 | 0.00 ± 0.0 (−0.3 to 0.1) | 0.712 *0.04*; *trivial* |
| Long possessions (#) | 2.6 ± 2.7 | 2.9 ± 2.8 | 0.30 ± 0.2 (−0.7 to 0.1) | 0.174 *0.02*; *trivial* |
| One-touch (#) | 5.1 ± 5.9 | 3.9 ± 3.4 | 1.20 ± 0.4 (0.43 to 1.9) | 0.002* *0.25*; *small* |
| Average time on the ball – long possessions (s) | 2.8 ± 0.9 | 2.8 ± 0.9 | 0.01 ± 0.1 (−0.1 to 0.2) | 0.818 *0.02*; *trivial* |
| Total time on the ball (s) | 9.7 ± 9.4 | 10.6 ± 9.5 | 0.85 ± 0.7 (−2.3 to 0.7) | 0.266 *0.10*; *trivial* |
| Time per possession (s) | 1.0 ± 0.7 | 1.1 ± 0.8 | 0.12 ± 0.1 (−0.3 to −0.1) | 0.040* *0.17*; *trivial* |

CI, confidence interval; m, metres; m/min, metres per minute; m/s, metres per second.
* $p < 0.05$.

**Table 3**
Within-group (pre-, mid, post-PHV) differences in physical and technical performance characteristics between chronological and bio-banded formats for maturity status.

| Metric | Pre-PHV Chronological | Pre-PHV Bio-banded | Pre-PHV Mean diff ± SD | Pre-PHV *p-Value*; *Cohen's d*; *inference* | Mid-PHV Chronological | Mid-PHV Bio-banded | Mid-PHV Mean diff ± SD | Mid-PHV *p-Value*; *Cohen's d*; *inference* | Post-PHV Chronological | Post-PHV Bio-banded | Post-PHV Mean diff ± SD | Post-PHV *p-Value*; *Cohen's d*; *inference* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Physical characteristics* | | | | | | | | | | | | |
| Distance covered (m) | 1678.3 ± 484.8 | 1746.8 ± 480.2 | 68.5 ± 55.9 | *1.000*; *0.15*; *trivial* | 1899.8 ± 363.2 | 1862.2 ± 465.4 | 37.5 ± 56.3 | *1.000*; *0.08*; *trivial* | 1808.7 ± 475.3 | 2065.3 ± 421.8 | 256.6 ± 90.1 | *0.068*; *0.57*; *moderate* |
| Work rate (m/min) | 83.8 ± 24.1 | 79.9 ± 22.2 | 3.88 ± 2.7 | *1.000*; *0.17*; *trivial* | 94.3 ± 17.7 | 89.1 ± 22.5 | 5.2 ± 2.7 | *0.817*; *0.24*; *small* | 89.1 ± 23.2 | 98.2 ± 19.5 | 9.1 ± −2.1 | *0.557*; *0.42*; *small* |
| High intensity work rate (m/min) | 8.6 ± 5.9 | 8.1 ± 5.4 | 0.5 ± 0.8 | *1.000*; *0.07*; *trivial* | 12.3 ± 5.9 | 12.2 ± 6.9 | 0.2 ± 0.8 | *1.000*; *0.04*; *trivial* | 12.1 ± 8.5 | 15.6 ± 7.9 | 3.4 ± 1.2 | *0.109*; *0.54*; *moderate* |
| Sprint work rate (m/min) | 0.7 ± 1.01 | 0.7 ± 1.2 | 0.5 ± 0.2 | *1.000*; *0.03*; *trivial* | 1.6 ± 1.7 | 1.8 ± 1.9 | 0.2 ± 0.2 | *1.000*; *0.12*; *trivial* | 1.8 ± 2.0 | 2.3 ± 1.9 | 0.5 ± 0.3 | *1.000*; *0.23*; *small* |
| Sprint count (#) | 2.2 ± 2.8 | 2.4 ± 3.6 | 0.2 ± 0.5 | *1.000*; *0.05*; *trivial* | 5.0 ± 3.7 | 5.0 ± 4.1 | 0.00 ± 0.5 | *1.000*; *0.13*; *trivial* | 5.5 ± 5.1 | 6.7 ± 4.8 | 1.2 ± −1.5 | *1.000*; *0.31*; *small* |
| Top speed (m/s) | 5.5 ± 0.7 | 5.6 ± 0.8 | 0.1 ± 0.2 | *1.000*; *0.11*; *trivial* | 6.1 ± 0.7 | 6.1 ± 0.7 | 0.0 ± −0.3 | *1.000*; *0.8*; *trivial* | 6.2 ± 0.7 | 6.3 ± 0.6 | 0.1 ± 0.1 | *1.000*; *0.14*; *trivial* |
| HID covered (m) zone 1 [>4 (m/s)] | 173.7 ± 118.7 | 178.4 ± 117.6 | 4.6 ± 16.3 | *1.000*; *0.03*; *trivial* | 248.9 ± 118.6 | 252.2 ± 136.5 | 3.1 ± 16.5 | *1.000*; *0.02*; *trivial* | 244.9 ± 171.4 | 328.7 ± 168.8 | 83.8 ± 26.3 | *0.024**; *0.63*; *moderate* |
| SD covered (m) [>5.5 (m/s)] | 13.7 ± 21.6 | 15.9 ± 26.7 | 2.2 ± 4.1 | *1.000*; *0.06*; *trivial* | 33.3 ± 35.9 | 37.5 ± 38.4 | 4.2 ± 4.1 | *1.000*; *−0.12*; *trivial* | 36.5 ± 40.7 | 49.0 ± 41.5 | 12.4 ± 6.6 | *0.927*; *0.37*; *small* |
| Intense speed changes acc/decl actions (#) [>2.6 (m/s$^2$)] | 9.5 ± 6.4 | 8.7 ± 6.1 | 0.7 ± 0.9 | *1.000*; *0.09*; *trivial* | 14.1 ± 7.5 | 13.3 ± 8.1 | 0.7 ± 0.9 | *1.000*; *0.09*; *trivial* | 15.2 ± 10.4 | 17.6 ± 11.4 | 3.5 ± 1.3 | *0.120*; *0.45*; *small* |
| Intense speed changes acc/decl actions per min (#/min) | 0.5 ± 0.3 | 0.4 ± 0.3 | 0.1 ± 0.1 | *1.000*; *0.18*; *trivial* | 0.7 ± 0.4 | 0.6 ± 0.4 | 0.1 ± 0.1 | *1.000*; *0.12*; *trivial* | 0.7 ± 0.5 | 0.8 ± 0.5 | 0.1 ± 0.1 | *1.000*; *0.23*; *small* |
| *Technical characteristics* | | | | | | | | | | | | |
| Total touches (#) | 22.5 ± 16.2 | 24.0 ± 17.1 | 1.4 ± 2.1 | *1.000*; *0.8*; *trivial* | 22.8 ± 17.5 | 22.3 ± 14.1 | 0.5 ± 2.2 | *1.000*; *0.03*; *trivial* | 37.2 ± 28.7 | 26.7 ± 12.1 | 10.6 ± 3.5 | *0.042**; *0.60*; *moderate* |
| Touches per min (#/min) | 1.1 ± 0.8 | 1.0 ± 0.8 | 0.1 ± 0.1 | *1.000*; *0.03*; *trivial* | 1.1 ± 0.9 | 1.0 ± 0.6 | 0.1 ± 0.1 | *1.000*; *0.05*; *trivial* | 1.8 ± 1.4 | 1.2 ± 0.5 | 0.6 ± 0.2 | *0.013**; *0.67*; *moderate* |
| Left foot touches (#) | 7.4 ± 8.3 | 7.0 ± 8.4 | 0.3 ± 1.2 | *1.000*; *0.03*; *trivial* | 6.9 ± 10.3 | 6.8 ± 9.3 | 0.1 ± 1.2 | *1.000*; *0.01*; *trivial* | 11.7 ± 14.0 | 10.1 ± 8.6 | 1.6 ± 1.9 | *1.000*; *0.17*; *trivial* |
| Right foot touches (#) | 15.1 ± 13.7 | 16.9 ± 15.3 | 1.8 ± 1.8 | *1.000*; *0.12*; *trivial* | 15.8 ± 12.9 | 15.4 ± 12.2 | 0.4 ± 1.8 | *1.000*; *0.03*; *trivial* | 25.5 ± 23.5 | 16.5 ± 11.5 | 8.9 ± 2.9 | *0.037**; *0.61*; *moderate* |
| Total possessions (#) | 8.8 ± 5.7 | 8.8 ± 5.6 | 0.0 ± 0.8 | *1.000*; *0.01*; *trivial* | 8.9 ± 7.6 | 8.3 ± 5.1 | 0.5 ± 0.8 | *1.000*; *0.07*; *trivial* | 14.5 ± 11.9 | 10.0 ± 5.9 | 4.5 ± 1.3 | *0.017**; *0.65*; *moderate* |
| Short possessions (#) | 1.7 ± 2.0 | 1.8 ± 1.7 | 0.1 ± 0.3 | *1.000*; *0.05*; *trivial* | 1.9 ± 2.1 | 1.9 ± 2.0 | 0.0 ± 0.2 | *1.000*; *0.01*; *trivial* | 2.6 ± 2.3 | 2.1 ± 2.2 | 0.5 ± 0.4 | *1.000*; *0.25*; *small* |
| Average time on the ball — short possessions (s) | 0.9 ± 0.3 | 1.0 ± 0.2 | 0.0 ± 0.0 | *1.000*; *0.12*; *trivial* | 1.0 ± 0.2 | 1.0 ± 0.2 | 0.0 ± 0.00 | *1.000*; *0.17*; *trivial* | 1.0 ± 0.2 | 0.9 ± 0.2 | 0.1 ± 0.1 | *1.000*; *0.08*; *trivial* |
| Long possessions (#) | 2.2 ± 2.2 | 2.7 ± 2.7 | 0.5 ± 0.5 | *1.000*; *0.18*; *trivial* | 2.3 ± 2.2 | 2.8 ± 2.7 | 0.5 ± 0.5 | *1.000*; *0.17*; *trivial* | 4.5 ± 4.1 | 4.0 ± 3.0 | 0.5 ± 0.5 | *1.000*; *0.40*; *small* |
| Average time on the ball — long possessions (s) | 2.8 ± 0.9 | 2.7 ± 0.8 | 0.2 ± 0.1 | *1.000*; *0.20*; *small* | 2.8 ± 0.9 | 2.9 ± 0.9 | 0.1 ± 0.1 | *1.000*; *0.11*; *trivial* | 3.0 ± 0.9 | 3.1 ± 1.0 | 0.1 ± 0.2 | *1.000*; *0.13*; *trivial* |
| One touch (#) | 4.8 ± 3.9 | 4.2 ± 3.8 | 0.6 ± 0.6 | *1.000*; *0.12*; *trivial* | 4.5 ± 5.9 | 3.6 ± 2.6 | 0.9 ± 0.6 | *1.000*; *0.17*; *trivial* | 7.2 ± 8.7 | 3.8 ± 3.8 | 3.4 ± 0.9 | *0.006**; *0.71*; *moderate* |
| Total time on the ball (s) | 8.2 ± 8.0 | 9.4 ± 9.0 | 1.1 ± 1.1 | *1.000*; *0.12*; *trivial* | 8.7 ± 7.8 | 10.5 ± 9.9 | 1.8 ± 1.1 | *1.000*; *−0.19*; *trivial* | 16.0 ± 13.3 | 14.1 ± 8.8 | 1.9 ± 1.8 | *1.000*; *0.21*; *small* |
| Time per possession (s) | 0.9 ± 0.7 | 1.0 ± 0.7 | 0.1 ± 0.1 | *1.000*; *0.15*; *trivial* | 1.0 ± 0.7 | 1.1 ± 0.7 | 0.01 ± 0.1 | *1.000*; *0.08*; *trivial* | 1.2 ± 0.7 | 1.6 ± 0.9 | 0.4 ± 0.1 | *0.394*; *0.45*; *small* |

CI, confidence interval; m, metres; m/min, metres per minute; m/s, metres per second.
* $p < 0.05$.

**Table 4**
Within-group (early, on-time or late) differences in physical and technical performance characteristics between chronological and bio-banded formats for maturity timing.

| Metric | Early<br>Mean diff ± SD<br>*p-Value*; *Cohen's d*; *inference* | | On-time<br>Mean diff ± SD<br>*p-Value*; *Cohen's d*; *inference* | | Late<br>Mean diff ± SD<br>*p-Value*; *Cohen's d*; *inference* | |
|---|---|---|---|---|---|---|
| | Chronological | Bio-banded | Chronological | Bio-banded | Chronological | Bio-banded |
| *Physical characteristics* | | | | | | |
| Distance covered (m) | 1911.2 ± 294.3 | 2025.5 ± 499.3 | 1770.0 ± 443.7 | 1816.9 ± 484.2 | 1851.1 ± 529.1 | 1893.6 ± 335.3 |
| | 114.1 ± 116 | | 46.9 ± 41.7 | | 42.5 ± 112.8 | |
| | *1.000*; *0.24*; *small* | | *1.000*; *0.10*; *trivial* | | *1.000*; *0.09*; *trivial* | |
| Work rate (m/min) | 95.3 ± 14.6 | 93.5 ± 24.1 | 87.9 ± 21.8 | 85.3 ± 23.2 | 95.3 ± 14.6 | 93.5 ± 24.1 |
| | 1.8 ± 5.6 | | 2.6 ± 2.0 | | 2.6 ± 5.4 | |
| | *1.000*; *0.08*; *trivial* | | *1.000*; *0.11*; *trivial* | | *1.000*; *0.11*; *trivial* | |
| High intensity work rate (m/min) | 13.7 ± 6.7 | 14.5 ± 7.7 | 10.3 ± 6.5 | 10.7 ± 6.9 | 13.7 ± 6.7 | 14.5 ± 7.7 |
| | 0.8 ± 1.7 | | 0.3 ± 0.6 | | 1.7 ± 1.6 | |
| | *1.000*; *0.12*; *trivial* | | *1.000*; *0.05*; *trivial* | | *1.000*; *0.24*; *small* | |
| Sprint work rate (m/min) | 2.1 ± 2.5 | 2.0 ± 1.9 | 1.1 ± 1.5 | 1.4 ± 1.8 | 2.1 ± 2.5 | 2.0 ± 1.9 |
| | 0.0 ± 0.4 | | 0.2 ± 0.1 | | 0.1 ± 0.4 | |
| | *1.000*; *0.04*; *trivial* | | *1.000*; *0.11*; *trivial* | | *1.000*; *0.05*; *trivial* | |
| Sprint count (#) | 5.5 ± 4.6 | 6.0 ± 5.6 | 3.7 ± 3.8 | 4.0 ± 4.2 | 3.8 ± 3.7 | 3.3 ± 3.0 |
| | 0.5 ± −1.0 | | 0.2 ± 0.4 | | 0.5 ± 1.0 | |
| | *1.000*; *0.12*; *trivial* | | *1.000*; *0.05*; *trivial* | | *1.000*; *0.11*; *trivial* | |
| Top Speed (m/s) | 6.3 ± 0.7 | 6.0 ± 0.7 | 5.8 ± 0.7 | 5.9 ± 0.8 | 5.9 ± 0.7 | 6.1 ± 0.7 |
| | 0.2 ± 0.2 | | 0.1 ± 0.1 | | 0.1 ± 0.2 | |
| | *1.000*; *0.22*; *small* | | *1.000*; *0.07*; *trivial* | | *1.000*; *0.15*; *trivial* | |
| HID covered (m) zone 1 [>4 (m/s)] | 274.9 ± 133.8 | 313.6 ± 162.3 | 208.3 ± 131.2 | 225.3 ± 142.4 | 228.2 ± 136.2 | 203.1 ± 117.4 |
| | 38.6 ± 34.8 | | 16.9 ± 12.5 | | 25.1 ± 33.7 | |
| | *1.000*; *0.28*; *small* | | *1.000*; *0.12*; *trivial* | | *1.000*; *0.18*; *trivial* | |
| SD covered (m) [>5.5 (m/s)] | 42.6 ± 51.5 | 44.2 ± 42.9 | 24.0 ± 30.7 | 28.8 ± 36.4 | 23.7 ± 25.7 | 22.8 ± 27.8 |
| | 1.6 ± 8.8 | | 4.8 ± 3.1 | | 0.9 ± 8.5 | |
| | *1.000*; *0.05*; *trivial* | | *1.000*; *0.13*; *trivial* | | *1.000*; *0.02*; *trivial* | |
| Intense speed changes acc/decl actions (#) [>2.6 ($m/s^2$)] | 15.1 ± 7.9 | 16.4 ± 11.0 | 11.8 ± 7.9 | 11.6 ± 8.4 | 13.5 ± 8.3 | 11.0 ± 6.3 |
| | 1.3 ± 2.1 | | 0.3 ± 0.8 | | 2.5 ± 2.0 | |
| | *1.000*; *0.15*; *trivial* | | *1.000*; *0.03*; *trivial* | | *1.000*; *0.30*; *small* | |
| Intense speed changes acc/decl actions per min (#/min) | 0.8 ± 0.3 | 0.8 ± 0.5 | 0.6 ± 0.4 | 0.6 ± 0.4 | 0.7 ± 0.4 | 0.5 ± 0.3 |
| | 0.0 ± 0.1 | | 0.0 ± 0.0 | | 0.2 ± 0.1 | |
| | *1.000*; *0.01*; *trivial* | | *1.000*; *0.09*; *trivial* | | *1.000*; *0.38*; *small* | |
| *Technical characteristics* | | | | | | |
| Total touches (#) | 27.7 ± 16.6 | 24.1 ± 25.3 | 24.7 ± 20.9 | 23.4 ± 13.8 | 24.8 ± 17.7 | 26.5 ± 15.1 |
| | 3.6 ± 4.5 | | 1.3 ± 1.6 | | 1.8 4.4 | |
| | *1.000*; *0.20*; *small* | | *1.000*; *−0.19*; *trivial* | | *1.000*; *0.09*; *trivial* | |
| Touches per min (#/min) | 1.4 ± 0.8 | 1.0 ± 1.1 | 1.2 ± 1.0 | 1.1 ± 0.6 | 1.2 ± 0.8 | 1.2 ± 0.7 |
| | 0.3 ± 0.2 | | 0.1 ± 0.1 | | 0.0 ± 0.2 | |
| | *1.000*; *0.33*; *small* | | *1.000*; *0.14*; *trivial* | | *1.000*; *0.01*; *trivial* | |
| Left foot touches (#) | 8.6 ± 7.8 | 6.1 ± 6.8 | 8.0 ± 11.1 | 7.6 ± 9.2 | 6.8 ± 8.0 | 7.3 ± 7.2 |
| | 2.5 ± 2.4 | | 0.4 ± 0.9 | | 0.5 ± 2.4 | |
| | *1.000*; *0.26*; *small* | | *1.000*; *0.04*; *trivial* | | *1.000*; *0.05*; *trivial* | |
| Right foot touches (#) | 19.0 ± 13.9 | 17.9 ± 22.5 | 16.7 ± 16.4 | 15.7 ± 12.1 | 17.9 ± 14.4 | 19.1 ± 14.6 |
| | 1.1 ± 3.7 | | 0.1 ± 1.3 | | 1.2 ± 3.6 | |
| | *1.000*; *0.07*; *trivial* | | *1.000*; *0.06*; *trivial* | | *1.000*; *0.08*; *trivial* | |
| Total possessions (#) | 9.8 ± 5.1 | 7.7 ± 6.4 | 9.8 ± 8.4 | 8.9 ± 5.4 | 9.8 ± 8.1 | 8.9 ± 5.1 |
| | 2.0 ± 1.7 | | 0.8 ± 2.7 | | 0.8 ± 1.7 | |
| | *1.000*; *0.28*; *small* | | *1.000*; *0.12*; *trivial* | | *1.000*; *0.12*; *trivial* | |
| Short possessions (#) | 2.2 ± 1.6 | 1.5 ± 1.9 | 1.9 ± 2.1 | 2.0 ± 1.9 | 2.1 ± 2.4 | 1.6 ± 1.7 |
| | 0.7 ± 0.5 | | 0.1 ± 0.2 | | 0.5 ± 0.5 | |
| | *1.000*; *0.34*; *small* | | *1.000*; *0.03*; *trivial* | | *1.000*; *0.24*; *small* | |
| Average time on the ball — short possessions (s) | 1.0 ± 0.2 | 0.9 ± 0.2 | 1.0 ± 0.2 | 1.0 ± 0.2 | 1.0 ± 0.2 | 0.9 ± 0.2 |
| | 0.1 ± 0.1 | | −0.0 ± 0.0 | | 0.1 ± 0.1 | |
| | *1.000*; *0.21*; *small* | | *1.000*; *0.00*; *trivial* | | *1.000*; *0.30*; *small* | |
| Long possessions (#) | 3.1 ± 3.3 | 2.9 ± 3.1 | 2.6 ± 2.8 | 2.9 ± 2.7 | 2.8 ± 2.3 | 3.4 ± 2.6 |
| | 0.2 ± 0.7 | | 0.3 ± 0.2 | | −0.7 ± 0.7 | |
| | *1.000*; *0.05*; *trivial* | | *1.000;0.12*; *trivial* | | *1.000*; *0.24*; *small* | |
| Average time on the ball — long possessions (s) | 2.7 ± 0.6 | 2.9 ± 0.6 | 2.9 ± 0.9 | 2.8 ± 0.9 | 3.0 ± 1.0 | 3.1 ± 1.1 |
| | 0.1 ± 0.2 | | 0.1 ± 0.1 | | 0.1 ± 0.2 | |
| | *1.000*; *0.13*; *trivial* | | *1.000*; *0.04*; *trivial* | | *1.000*; *0.12*; *trivial* | |
| One-touch (#) | 4.5 ± 2.7 | 3.3 ± 2.5 | 5.3 ± 6.3 | 4.0 ± 3.5 | 4.9 ± 5.4 | 3.9 ± 2.8 |
| | 1.1± 1.2 | | 1.2 ± 0.4 | | 1.0 ± 1.2 | |
| | *1.000*; *0.23*; *small* | | *0.073*; *0.26*; *small* | | *1.000*; *0.21*; *small* | |
| Total time on the ball (s) | 11.0 ± 10.7 | 9.7 ± 10.3 | 9.5 ± 9.5 | 10.5 ± 9.4 | 10.1 ± 7.7 | 12.0 ± 9.2 |
| | 1.2± 2 | | 1.0 ± 0.8 | | 1.9 ± 2.3 | |
| | *1.000*; *0.13*; *trivial* | | *1.000*; *0.10*; *trivial* | | *1.000*; *0.20*; *small* | |
| Time per possession (s) | 1.1 ± 0.7 | 1.1 ± 0.6 | 1.0 ± 0.7 | 1.2 ± 0.8 | 1.1 ± 0.7 | 1.2 ± 0.7 |
| | 0.1 ± 0.2 | | 0.2 ± 0.1 | | 0.1 ± 0.2 | |
| | *1.000*; *0.07*; *trivial* | | *0.403*; *0.20*; *small* | | *1.000*; *0.05*; *trivial* | |

CI, confidence interval; m, metres; m/min, metres per minute; m/s, metres per second

### 4.2. Between-maturity-group physical differences

Except for distance covered in the bio-banded format, there were significant differences ($p = 0.000$–$0.016$) between pre-PHV and mid-PHV for all physical characteristics measured in both formats ($d = 0.48$–$0.79$) (Fig. 2). This trend is similar when comparing pre-PHV and post-PHV in that, except for distance covered and work rate in the chronological format, there were significant differences ($p = 0.000$–$0.016$) between pre-PHV and post-PHV in all other physical characteristics across both formats ($d = 0.53$–$1.16$). There were no significant differences ($p = >0.005$) in physical characteristics between mid-PHV and post-PHV in the chronological format, but significantly ($p = 0.014$–$0.041$) greater high-intensity work rate ($d = 0.52$) and high-intensity distance covered ($d = 0.58$) for post-PHV versus mid-PHV during bio-banded matches (Fig. 2).

### 4.3. Between-maturity-group technical differences

In contrast to physical, there are no significant differences ($p = >0.005$) in technical characteristics between pre-PHV and mid-PHV groups in either match format (Fig. 3). The differences emerged between pre-PHV and post-PHV in the chronological format with post-PHV having greater total time on the ball ($p = 0.000$, $d = 0.84$), number of one-touch possessions ($p = 0.038$, $d = 0.49$), total touches ($p = 0.000$, $d = 0.84$), long possessions ($p = 0.000$, $d = 0.86$), total possessions ($p = 0.000$, $d = 0.82$), right foot touches ($p = 0.000$, $d = 0.70$) and touches per minute ($p = 0.000$, $d = 0.83$). There were also significant differences in technical characteristics between mid-PHV and post-PHV, with post-PHV players having more time on the ball ($p = 0.000$, $d = 0.79$), one-touch possessions ($p = 0.038$, $d = 0.55$), total touches ($p = 0.000$, $d = 0.82$), long possessions ($p = 0.000$, $d = 0.82$), total possessions ($p = 0.000$, $d = 0.81$), right ($p = 0.000$, $d = 0.65$) and left foot touches ($p = 0.030$, $d = 0.49$) and higher frequency of touches per minute ($p = 0.000$, $d = 0.82$) in chronological formats only. This was not replicated in the bio-banded format, with the only significant difference between any group being the time per possession ($p = 0.002$, $d = 0.66$) between mid-PHV and post-PHV (Fig. 3).

## 5. Discussion

This study examined the physical and technical characteristics of youth soccer players during 11v11 chronological and bio-banded match play using F-IMU technology. We hypothesised that there would be no differences in physical and technical characteristics between formats and that bio-banding would place increased demands on more mature players, potentially supporting more equitable and balanced experiences. The main findings partially agreed with our hypothesis in that 1) the baseline inertia of each PLSCA model was low, suggesting that overall, there was a weak relationship between physical, technical and time on the ball characteristics and match format, and 2) whole sample analysis revealed no differences in physical characteristics between chronological and bio-banded matches. However, reductions in one-touch possessions and an increase in total time per possession were observed in the bio-banded format for the whole sample. Within-group analysis revealed that reduced ball involvement and increased high-intensity distance were evident in post-PHV players in the bio-banded format, but there was no impact of format on the physical or technical characteristics of pre- and mid-PHV players, as per our hypothesis. There were, however, *moderate* to *large* between-maturity group differences in physical characteristics in both formats, demonstrating a maturity-aligned increase in physical demand. Interestingly, these differences were not reflected in technical characteristics.

### 5.1. Bio-banding versus chronological format and technical performance

Bio-banding is thought to diminish mismatches in size and performance caused by biological maturation.[8] However, its adoption in talent development has been slow, likely due to uncertainty over whether the logistics (e.g., coordinating players, coaches, and team preparation), ethics (e.g., players competing up or down, parental concerns), and overall efficacy (i.e., mediating of advantages/disadvantages) outweigh its benefits.[14] Initially, when analysing whole-sample findings, we demonstrate why practitioners may question the efficacy of bio-banding (Table 2). There are *trivial* differences between formats, except for reduced one-touch possessions and increased time per possession. This is likely due to bio-banding altering the nature of the match in different ways for players at varying stages of maturity, resulting in a nullified overall response. For example, the reduced one-touch possessions and increased time per possession might originate from less mature players having increased confidence to take touches and thus spend longer on the ball in the bio-banded format.[16,28,30] But this may be reversed for more mature players who may feel less confident in bio-banded matches based on the relatively higher physical challenge compared to chronological matches, thus rendering whole-group differences *trivial* or *small*. As a result, and at face value, talent development personnel may question the efficacy of implementing bio-banding, considering the logistical and ethical constraints associated with it. However, the whole-group trivial findings only reveal part of the picture and highlight the need to further examine maturity-specific responses to appreciate how bio-banding could be harnessed to optimise development.

### 5.2. Post-PHV players and bio-banding

Cumming et al.[16] found that players who mature early tend to rely on physical attributes in standard chronological-age matches, a notion supported by King et al.,[26] but bio-banding forces them to adopt a more technical and tactical playing style. Our findings show that for post-PHV players, decreased ball involvement and increased high-intensity distances were evident in the bio-banding format. When we unpacked that further, post-PHV players had significantly more ball involvement than pre-PHV players in chronological matches, but this was not evident in bio-banded matches. This supports the notion that post-PHV players dominate chronological formats due to their advanced maturity, as previously reported.[17,26] Bio-banding perhaps helps to minimise this advantage, leading to a more balanced distribution of ball involvement (Table 3). This enhances the challenge faced by early developing players and likely enhances their holistic development, emphasising technique, effective decision-making and increased high-intensity outputs while simultaneously allowing maturity-disadvantaged players an opportunity to play with reduced apprehension around their physical capability and exerting greater influence on the game through their technical and tactical proficiency.[16]

Despite whole-group analysis suggesting *trivial* changes in the physical outputs between formats, sub-group analysis demonstrates consistent, meaningful differences between maturity groups across both formats (Fig. 2). Generally, physical demands increased with maturation, with the largest differences occurring between pre-PHV and mid-PHV players. This progressive increase aligns with previous research[41] and is attributable to enhanced physical outputs associated with increased maturation.[42,43] These progressive differences were observed in both formats suggesting that grouping players according to biological maturity does not remove the maturity-specific trends but perhaps infers that bio-banding may offer a mechanism to minimise overreaching for less mature players. For example, increases in injury incidence and burden as players progress through maturation[44] are likely associated with the relatively increased physical demands presented here for more mature players. Therefore, bio-banding may help regulate maturity-specific intensities, allowing more developed players to compete at higher intensities without imposing these demands on less

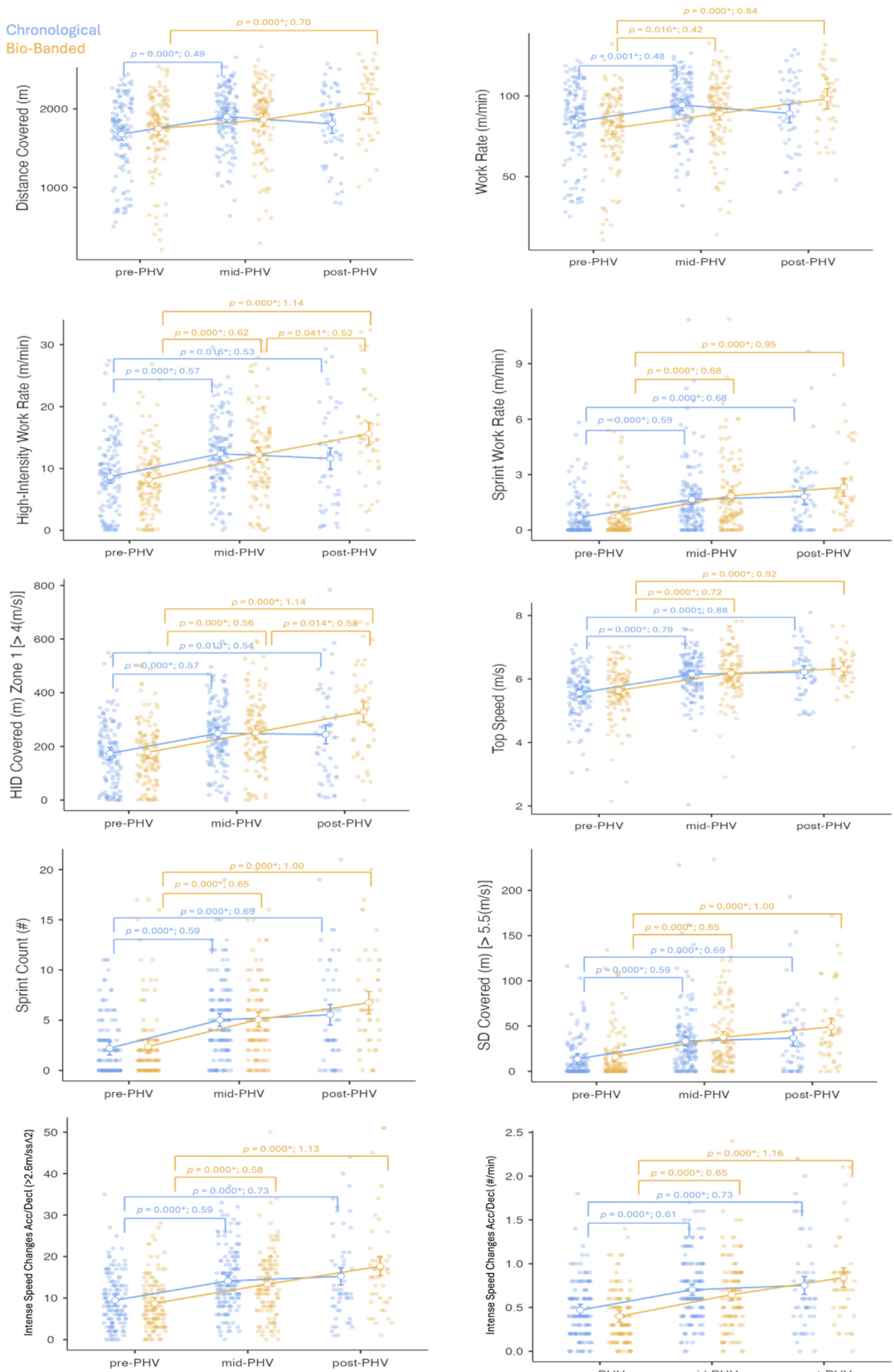


**Fig. 2.** Estimated marginal mean differences (mean ± SD with 95 % confidence intervals) in physical characteristics between chronological and bio-banded formats across biological maturity groups. Statistically significant differences between groups are highlighted (*p*-value; Cohen's-*d*).

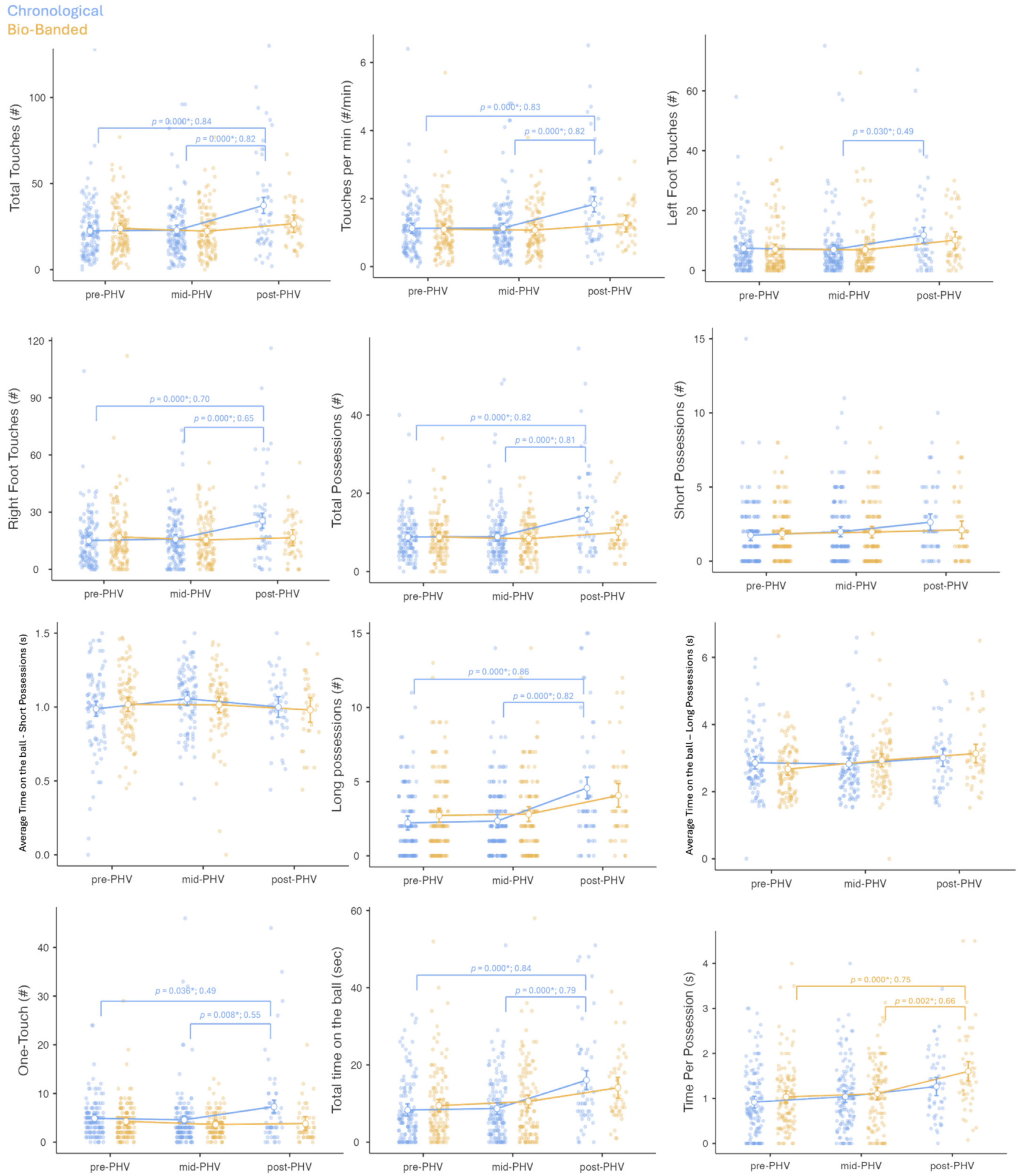


**Fig. 3.** Estimated marginal mean differences (mean ± SD with 95 % confidence intervals) in technical characteristics between chronological and bio-banded formats across biological maturity groups. Statistically significant differences between groups are highlighted (*p*-value; Cohen's-*d*).

mature individuals, allowing them to compete at a safer and more developmentally appropriate level. Subsequently, it is limiting accumulated load maladaptation and reducing the likelihood of injury through overreaching.[4,45] Importantly, differences in physical characteristics were not mirrored in technical characteristics (Fig. 3). In the chronological format, there were *moderate* to *large* differences in technical actions between mid-PHV and post-PHV; however, bio-banding almost entirely (except for time per possession) removed these differences. Therefore, bio-banding may offer maturity-appropriate load regulation alongside greater parity in technical involvement and thus should appeal as a useful strategy to optimise development within talent pathways.

### *5.3. Limitations and future directions*

Although maturity-group differences are clear, there were no such differences in players who differ in maturity timing (Table 4). This suggests that any potential positives associated with bio-banding may support the development of early, on-time and late developers equally. The absence of difference may also be due to 78 % of the sample being categorised as on-time. Indeed, the sample sizes for early and late maturers were small and consequently lacked sufficient statistical power to report significant differences. In addition, the number of comparisons across the various formats and groups may lead to spurious findings, and there may be interrelated results between similar variables (e.g., total touches, touches on the right/left), which should be interpreted with caution. The authors also acknowledge that the method for categorising maturity timing differs from previous studies,[46] but we consider that our approach represents an ecologically valid approach that can be readily deployed in development pathways. We also acknowledge that although bio-banding reduced the heterogeneity across the groups by ~30 %, there was still considerable variability within each group, which suggests that alternative methods to bio-band players (i.e., biological age grouping) may offer greater reduction in biological diversity, although they may face logistical complexities. It is important to state that the metrics used to observe the nature of match-play between two formats from the F-IMUs are not typically used to inform talent selection, and therefore, coach/scout evaluations of players in this format would also be advantageous. This study also employed standardised, youth-specific absolute thresholds for locomotive velocities used by the F-IMU provider, which outlines match-play characteristics. Therefore, it is acknowledged that because of the variation in biological maturity across the sample, some players will be working at a lower relative intensity when entering different speed thresholds used by the F-IMUs, which may have influenced findings related to physical characteristics. However, to the research team's knowledge, there are no studies which identify maturity-specific running velocity thresholds in male football and only a single age-specific study in female populations,[47] which is not directly applicable to the male population in this study. We concede that the structure and single-day format of the event may confound findings, as we were unable to randomise the format order and that players may have experienced fatigue-related confounding in the bio-banded format. Finally, the findings of this study may not be generalisable to 'elite' or female populations; therefore, similar studies are required before these findings are applied to these populations.

## 6. Conclusion

This study examined physical and technical differences in 11v11 football matches between chronological and bio-banded formats using F-IMUs. No overall physical differences were found, but one-touch possessions were reduced, and there was increased time per possession evident in the bio-banded format. For post-PHV players, decreased ball involvement and increased high-intensity distances were observed in the bio-banded format, whilst pre- and mid-PHV players were unaffected. Physical demands remained higher for mid- and post-PHV players across both formats, but technical actions were unaffected. As such, bio-banding perhaps has the potential to balance technical actions, reducing the dominance of physically mature players and supporting holistic development. In this way, bio-banding may complement chronological age grouping by moderating physical demands and enhancing technical growth, helping practitioners make more informed decisions about holistic player development. As a result of these findings, practitioners are encouraged to supplement the chronological age programme with periodic bio-banding activities that expose players at all maturity stages to diverse physical and technical challenges. In turn, this may enhance long-term development by nurturing attributes that are typically obscured within a highly biologically diverse age-driven development pathway.

## CRediT authorship contribution statement

**Salter, J:** Conceptualisation, original draft writing, and editing. **Forsdyke, D:** Conceptualisation, investigation, and reviewing. **Arenas, L:** Investigation and reviewing. **King, M:** Investigation and reviewing. **Myhill, N:** Investigation, data curation, and reviewing. **Robinson, J:** Investigation and reviewing. **Towlson, C:** Original draft preparation and editing. **Springham, M:** Original draft preparation and editing. **Walsh, L:** Investigation and reviewing. **Mallinson-Howard, S:** Methodology, investigation, and reviewing. **Barrett, S:** Methodology, investigation, and reviewing.

## Confirmation of ethical compliance

The study was conducted by all applicable ethical standards and received full ethical approval from the York St John University, Science, Technology and Health Ethics Committee (ETH2425-0017). Following this parental consent and participant assent were obtained electronically following an online webinar by the research team to outline research objectives prior to any data collection.

## Funding information

There was no funding associated with the development of this project and manuscript.

## Declaration of interest statement

Playermaker did not provide any financial funding for the project. The last author of this study is employed by the company that provided the F-IMUs used to collect players' technical and physical performance data. However, to avoid any perceived bias, the last author was not involved in the statistical analysis of the data in this study. There are no other conflicts of interest.

## Acknowledgements

The authors thank the Junior Premier League and Playermaker for their collaboration and assistance in this research.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2025.09.006.

## Data availability

Data file available via a private link via YSJU open repository (RayDar): https://figshare.com/s/6c8a6a566a0a631d6971.

## References

1. Baker J, Wattie N, Schorer J. A proposed conceptualization of talent in sport: the first step in a long and winding road. *Psychol Sport Exerc* 2019;43:27-33. doi:10.1016/j.psychsport.2018.12.016.
2. Sedeaud A, Difernand A, De Larochelambert Q et al. Talent identification: time to move forward on estimation of potentials? Proposed explanations and promising methods. *Sports Med* 2025. doi:10.1007/s40279-024-02171-5.
3. Towlson C, Salter J, Ade J et al. Maturity-associated considerations for training load, injury risk, and physical performance within youth soccer: one size does not fit all. *J Sport Health Sci* 2020. doi:10.1016/j.jshs.2020.09.003.
4. Salter J. Small-sided-game-induced mechanical load in adolescent soccer: the need for care and consideration for athlete preservation. *Sports Health* 2024;17(1):39-45. doi:10.1177/19417381241296063.

5. Figueiredo AJ, Silva MJCe, Cumming SP et al. Size and maturity mismatch in youth soccer players 11- to 14-years-old. *Pediatr Exerc Sci* 2010;22(4):596-612. doi:10.1123/pes.22.4.596.
6. Cumming S, Lloyd RS, Oliver JL et al. Bio-banding in sport: applications to competition, talent identification, and strength and conditioning of youth athletes. *Strength Cond J* 2017;39(2):34-47. doi:10.1519/SSC.0000000000000281.
7. Philippaerts RM, Vaeyens R, Janssens M et al. The relationship between peak height velocity and physical performance in youth soccer players. *J Sports Sci* 2006;24(3): 221-230. doi:10.1080/02640410500189371.
8. Chimera NJ, Falk B, Klentrou P et al. Is biobanding the future of youth sport participation? *Pediatr Exerc Sci* 2024:1-11. doi:10.1123/pes.2024-0021.
9. Towlson C, Cobley S, Midgley A et al. Relative age, maturation and physical biases on position allocation in elite-youth soccer. *Int J Sports Med* 2017;38(03):201-209. doi:10.1055/s-0042-119029.
10. Malina RM, Cumming SP, Rogol AD et al. Bio-banding in youth sports: background, concept, and application. *Sports Med* 2019;49(11):1671-1685. doi:10.1007/s40279-019-01166-x.
11. De La Rubia A, Kelly AL, García-González J et al. Biological maturity vs. relative age: independent impact onphysical performance in male and female youth handball players. *Biol Sport* 2024;41(3):3-13. doi:10.5114/biolsport.2024.132999.
12. Lindholm O, Niklasson E, Lind J et al. A pilot study on bio-banding in male youth ice hockey: players' perceptions and coaches' selection preferences. *PloS One* 2024;19 (8):e0308676. doi:10.1371/journal.pone.0308676.
13. Arenas L, Frenger M, Skorski S et al. Survey of the current practices of German football academies towards biological maturation assessment. *Sci Med Footb* 2023;24733938 (2023):2270563. doi:10.1080/24733938.2023.2270563.
14. Salter J, De Ste Croix MBA, Hughes JD et al. Monitoring practices of training load and biological maturity in UK soccer academies. *Int J Sports Physiol Perform* 2020;16(3): 395-406.
15. Towlson C, Cumming SP. Bio-banding in soccer: past, present, and future. *Ann Hum Biol* 2022;1–12. doi:10.1080/03014460.2022.2129091.
16. Cumming S, Brown DJ, Mitchell S et al. Premier League academy soccer players' experiences of competing in a tournament bio-banded for biological maturation. *J Sports Sci* 2018;36(7):757-765. doi:10.1080/02640414.2017.1340656.
17. MacMaster C, Portas M, Parkin G et al. The effect of bio-banding on the anthropometric, physical fitness and functional movement characteristics of academy soccer players. *PloS One* 2021;16(11):e0260136. doi:10.1371/journal.pone.0260136.
18. Johnson D, Williams S, Bradley B et al. Can we reduce injury risk during the adolescent growth spurt? An iterative sequence of prevention in male academy footballers. *Ann Hum Biol* 2023;50(1):452-460. doi:10.1080/03014460.2023.2261854.
19. Malina RM, Rogol A, Cumming S et al. Biological maturation of youth athletes: assessment and implications. *Br J Sports Med* 2015;49:852-859. doi:10.1136/bjsports-2015-094623.
20. Khamis HJ, Roche AF. Predicting adult stature without using skeletal age: the Khamis-Roche method. *Pediatrics* 1994;94(4):504-507.
21. Parr J, Winwood K, Hodson-Tole E et al. Predicting the timing of the peak of the pubertal growth spurt in elite youth soccer players: evaluation of methods. *Ann Hum Biol* 2020;0(ja):1-23. doi:10.1080/03014460.2020.1782989.
22. Towlson C, Watson DJ, Cumming S et al. Soccer academy practitioners' perceptions and application of bio-banding. *PloS One* 2023;18(1):e0274079. doi:10.1371/journal.pone.0274079.
23. Abbott W, Williams S, Brickley G et al. Effects of bio-banding upon physical and technical performance during soccer competition: a preliminary analysis. *Sports* 2019;7 (8):193. doi:10.3390/sports7080193.
24. Romann M, Lüdin D, Born D-P. Bio-banding in junior soccer players: a pilot study. *BMC Res Notes* 2020;13(1):240. doi:10.1186/s13104-020-05083-5.
25. Arede J, Radnor JM, Gonzalo-Skok O et al. Chronological age-based vs. bio-banded friendly football tournament: effects on physical performance and spatial exploration behaviour in 7v7 match play. *J Sports Sci* 2024:1-9. doi:10.1080/02640414.2024.2328968.
26. King M, Barrett S, Mclellan R et al. Does team size affect Scottish male academy soccer player technical, locomotor and psychosocial outcomes during age and maturity bio-banded small-sided games? *J Sports Sci* 2025;0(0):1-11. doi:10.1080/02640414.2025.2456408.
27. Salter J, Cumming S, Hughes JD et al. Estimating somatic maturity in adolescent soccer players: methodological comparisons. *Int J Sports Sci Coach* 2021: 17479541211020418. doi:10.1177/17479541211020418.
28. Bradley B, Johnson D, Hill M et al. Bio-banding in academy football: player's perceptions of a maturity matched tournament. *Ann Hum Biol* 2019;46(5):400-408. doi:10.1080/03014460.2019.1640284.
29. Towlson C, MacMaster C, Gonçalves B et al. The effect of bio-banding on technical and tactical indicators of talent identification in academy soccer players. *Sci Med Footb* 2022;6(3):295-308. doi:10.1080/24733938.2021.2013522.
30. Lüdin D, Donath L, Cobley S et al. Effect of bio-banding on physiological and technical-tactical key performance indicators in youth elite soccer. *Eur J Sport Sci* 2021. doi:10.1080/17461391.2021.1974100.
31. Cumming S, Pi-Rusiñol R, Rodas G et al. The validity of automatic methods for estimating skeletal age in young athletes: a comparison of the BAUSport ultrasound system and BoneXpert with the radiographic method of Fels. *Biol Sport* 2024;41(1):61-67. doi:10.5114/biolsport.2024.127380.
32. Petri C, Campa F, Holway F et al. ISAK-based anthropometric standards for elite male and female soccer players. *Sports* 2024;12(3):3. doi:10.3390/sports12030069.
33. Epstein LH, Valoski AM, Kalarchian MA et al. Do children lose and maintain weight easier than adults: a comparison of child and parent weight changes from six months to ten years. *Obes Res* 1995;3(5):411-417. doi:10.1002/j.1550-8528.1995.tb00170.x.
34. Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity, *Human Kinetics*, 2004.
35. Marris J, Barrett S, Abt G et al. Quantifying technical actions in professional soccer using foot-mounted inertial measurement units. *Sci Med Footb* 2021;24733938 (2021):1910333. doi:10.1080/24733938.2021.1910333.
36. Myhill N, Weaving D, Robinson M et al. Concurrent validity and between-unit reliability of a foot-mounted inertial measurement unit to measure velocity during team sport activity. *Sci Med Footb* 2024;8(4):308-316. doi:10.1080/24733938.2023.2237493.
37. King M, Brown M, Cox J et al. Talent identification in soccer: the influence of technical, physical and maturity-related characteristics on a national selection process. *PloS One* 2024;19(3):e0298359. doi:10.1371/journal.pone.0298359.
38. Myhill N, Weaving D, Barrett S et al. A multi-club analysis of the locomotor training characteristics of elite female soccer players. *Sci Med Footb* 2022;6(5):572-580. doi:10.1080/24733938.2022.2114603.
39. Weaving D, Jones B, Ireton M et al. Overcoming the problem of multicollinearity in sports performance data: a novel application of partial least squares correlation analysis. *PloS One* 2019;14(2):e0211776. doi:10.1371/journal.pone.0211776.
40. Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol* 2013;4. doi:10.3389/fpsyg.2013.00863.
41. Connolly DR, Stolp S, Gualtieri A et al. How do young soccer players train? A 5-year analysis of weekly training load and its variability between age groups in an elite youth academy. *J Strength Cond Res* 2024;38(8):e423-e429. doi:10.1519/JSC.0000000000004813.
42. Gundersen H, Kvammen KMN, Vestbøstad M et al. Relationships between bone age, physical performance, and motor coordination among adolescent male and female athletes. *Front Sports Act Living* 2024;6:1435497. doi:10.3389/fspor.2024.1435497.
43. Negra Y, Sammoud S, Nevill AM et al. Change of direction speed in youth male soccer players: the predictive value of anthropometrics and biological maturity. *Pediatr Exerc Sci* 2022;1(aop):1-7. doi:10.1123/pes.2021-0178.
44. Materne O, Chamari K, Farooq A et al. Association of skeletal maturity and injury risk in elite youth soccer players: a 4-season prospective study with survival analysis. *Orthop J Sports Med* 2021;9(3):2325967121999113. doi:10.1177/2325967121999113.
45. Williams C, Winsley RJ, Pinho G et al. Prevalence of non-functional overreaching in elite male and female youth academy football players. *Sci Med Footb* 2017;1(3): 222-228. doi:10.1080/24733938.2017.1336282.
46. Sweeney L, Lundberg TR. Relative age and biological maturity-related selection biases in male youth soccer across different competitive levels within a national association. *Sci Med Footb* 2024:1-9. doi:10.1080/24733938.2024.2369543.
47. Harkness-Armstrong A, Till K, Datson N, Emmonds S. Determining age-specific velocity thresholds for elite youth female soccer players. *Sci Med Football* 2021;6(5):581-588. doi:10.1080/24733938.2021.1991585.
48. Lüdin D, Donath L, Romann M. Disagreement between talent scouts: Implications for improved talent assessment in youth football. *J Sports Sci* 2023;41(8):758-765. doi:10.1080/02640414.2023.2239614.