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Does team size affect Scottish male academy soccer player technical, locomotor and psychosocial outcomes during age and maturity bio-banded small-sided games?

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ABSTRACT

The timing of the adolescent growth spurt (i.e. peak height velocity [PHV]) varies greatly, causing significant differences in maturity-related anthropometric and physical development among chronologically age-categorised youth soccer players. These differences can lead to a maturity-selection bias favouring early maturing players. Using fifty-three players from two professional Scottish soccer academies, this study examined the effects of team size (4v4, 5v5, and 6v6) and bio-banding (i.e. grouping players by maturity status) on players technical (i.e. touches, releases, possessions), physical (i.e. distance covered, accelerations/decelerations), and psychological (i.e. confidence, competitiveness, positive attitude) performance during small-sided games, using foot-mounted inertial measurement units (F-IMU) and coach observations. Data were analysed using multivariate ANOVA. During maturity-matched games, technical actions decreased as team size increased. More mature players displayed greater technical actions in 4v4 compared to 6v6. Maturity-mismatched games revealed significant technical action differences for less mature players, particularly in 4v4 formats. More mature players covered greater high-intensity distances in maturity-matched and mismatched 6v6 games. Psychological scores were higher for more mature players in smaller team sizes (4v4), whereas less mature players showed consistent psychological scores across all formats. Smaller team sizes and maturity-matched bio-banding formats enhanced technical actions and psychological characteristics, particularly for more mature players.

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Talent identification; coaching strategies; growth; peak-height velocity

Introduction

The timing and tempo of child growth and physical development are independent of age (Philippaerts et al., 2006; Towlson et al., 2018). The highly-individualised timing of the adolescent growth spurt onset (commonly referred to as peak height velocity [PHV] (Fransen et al., 2021; Mirwald et al., 2002; Towlson et al., 2021)) within chronologically age-ordered groups of children is a causal factor for large variations in anthropometric growth (particularly stature and body-mass) (Bolckmans et al., 2022; Hannon et al., 2020; Helsen et al., 2021; MacMaster et al., 2021). The relative timing (i.e. early, or late) of PHV onset has been shown to exclusively (Towlson, MacMaster, Parr et al., 2022), underpin the maturity-selection bias which contributes toward the (sub)conscious over-selection of early maturing. For example, adolescent soccer players who are often characterised as having transient, superior stature and body-mass, compared to later maturing players (often characterised as having inferior stature and body-mass) for specialised youth soccer development programmes (Deprez et al., 2015; Lovell et al., 2015; Towlson et al., 2017). Such maturity-selection bias is of importance and relevance to professional soccer clubs, given the financial sanctions imposed by the Union of European Football Associations (UEFA) on clubs who do not operate within their financial means (Towlson et al., 2017). Subsequently the importance of optimising talent identification strategies, within soccer clubs, to develop their own players for the first team and sell on for profit. By optimising talent identification strategies, clubs can prioritise the development of homegrown players for the first team, thereby reducing recruitment costs and creating potential revenue through player transfers. The present study addresses this challenge by exploring how team size and maturity-based bio-banding influence the equitable evaluation of youth players, ensuring that talented individuals are identified irrespective of potential maturity-related advantages or disadvantages.

In addition to maturity-related anthropometric bias, maturation has also been shown to have some impact on youth soccer players technical-tactical characteristics (as quantified by use of the System of Tactical Assessment in Soccer (FUT-SAT)) (Teoldo et al., 2017), which may determine which players drop out, persist or progress through the development pathway (Figueiredo et al., 2009; Gonçalves et al., 2021). For instance, players who are more biologically mature have been found to possess a greater signal (i.e. identify important information), detection skills which have been shown to positively impact tactical behaviour efficiency of young soccer players (Gonçalves et al., 2021). Therefore, it is postulated that more mature players possess the temporary ability to perceive the game faster and

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more effectively and are likely able to provide quicker match-play responses (Gonçalves et al., 2021). In attempt to alleviate the confounding influence of maturation timing on talent identification, recategorizing players via maturity status rather than using arbitrary chronological age cut off points (commonly referred to as bio-banding (Malina et al., 2019; Towlson, Cumming, et al., 2022)) have been used (Abbott et al., 2019; Barrett et al., 2022; Lüdin et al., 2021; Towlson, Salter et al., 2021; Towlson et al., 2023). Bio-banding has been shown to remove the maturity-related variations in anthropometric characteristics (primarily stature and body-mass) which are evident within chronologically aged-ordered groups of players (MacMaster et al., 2021). To mitigate the confounding influence of maturation timing on talent identification, bio-banding has emerged as a promising strategy (Malina et al., 2019; Towlson, Cumming, et al., 2022). Bio-banding reduces maturity-related variations in anthropometric characteristics (e.g. stature and body mass), allowing more equitable playing environments where players can be evaluated based on their technical, physical, and psychological attributes rather than their temporary maturity advantages (MacMaster et al., 2021). Recent studies have demonstrated that bio-banding can enhance opportunities for less mature players to showcase their skills (Abbott et al., 2019; Lüdin et al., 2021), while also challenging more mature players to adapt to competitive scenarios without relying on physical dominance.

The effectiveness of bio-banding is influenced by contextual factors such as game format and relative pitch size, which can moderate the extent to which maturity-related advantages are neutralised (Towlson, MacMaster, Goncalves et al., 2022). However, the more removed the objective measure becomes from biological maturation, the less effective bio-banding is on reducing between player, maturity-related variations (MacMaster et al., 2021). Previous bio-banding studies have shown that on-time and later maturing players likely complete more short passes, complete less long passes and are afforded greater opportunity to dribble with the ball during maturity matched bio-banded match-play when compared to chronologically aged categorised matches (Abbott et al., 2019). In addition, the application of bio-banding has shown that later maturing players are likely afforded more opportunities to demonstrate technical and tactical skills during maturity matched bio-banding formats (Lüdin et al., 2021). The effects of bio-banding formats may be mediated by game constraints and relative pitch size (Towlson, MacMaster et al., 2021; Towlson, MacMaster, Parr et al., 2022), with small (52.6 m^2 per player) relative pitch size being shown to restrict likely technical and tactical (dis)advantages afforded to post-PHV players during maturity mis-matched bio-banded matches due to the higher density of players per square metre (Olthof et al., 2018) and limiting early maturing players from using their superior anthropometric and physical characteristics during match-play on a larger relative pitch size. In addition to technical and tactical characteristics, maturity-matched bio-banding has been shown to alleviate maturity-related differences in locomotor abilities (i.e. total distance, high-speed running and explosive distance) (Abbott et al., 2019; Towlson, MacMaster et al., 2021). However Lüdin et al., (2021) have shown that early maturing players perform more high intensity acceleration actions during matched bio-banded matches. Whilst Towlson, Salter et al. (2021) suggest that there may be few between maturity group differences in locomotor variables to start. Lastly, maturity mis-matched (e.g. pre-PHV vs post PHV) bio-banded small-sided games may afford pre-PHV players with a playing environment to let them exhibit a number of desirable psychological characteristics. Towlson, Salter et al. (2021) evidenced this by showing Pre-PHV and post-PHV players differing in practitioners' subjective psychological scores. These findings offer support for the 'underdog hypothesis'(Cumming et al., 2018; Gibbs et al., 2012) which suggests that later maturing players are more likely to develop superior psychological behaviours that permit them to compete with their more mature counterparts on absolute terms (Gibbs et al., 2012).

Despite convincing evidence to advocate the application of bio-banding during small-sided games (Abbott et al., 2019; Bradley et al., 2019; Hill et al., 2020; Lüdin et al., 2021; Towlson et al., 2023), only Towlson, MacMaster et al. (2021) have examined the effect of game constraint (relative pitch size) manipulation on its efficacy. Therefore, the purpose of this study was to examine the effect of maturity-matched and miss-matched bio-banding on perceived important soccer-specific metrics of technical, tactical, physical and psychological player performance during small-sided games when contested by teams comprised of a different number of players (4v4, 5v5 and 6v6), whilst controlling for relative pitch size.

Methods

Participants

Fifty-three youth players (age 13.4 ± 0.9 years, stature 161.4 ± 10.8 cm and body mass 49.5 ± 10 kg) from two professional Scottish Premier League soccer clubs were recruited for this study. To be considered for inclusion in the study, the player had to be a signed player of the youth academy at their respective club. With reference to the Mckay framework, which was presented to assist in defining training and performance calibre in sport science and sport medicine literature (McKay et al., 2022), the players would be considered 'Tier 2: Trained/Developmental'. Initially, only 48 players were due to complete the study; however, in the third week of testing, five players withdrew from the study due to injury (injuries did not occur during the study) and were replaced with players of a similar maturity status to ensure that the efficacy of the study was maintained. Despite being replaced in the third week of testing, the injured player's data was still included in the study for the first two weeks, and the replacement players provided the data for the third week, thus the inclusion of 53 players. All replacement players came from the same academy as players included in the first instance and therefore were deemed to be of the same playing standard. It was also ensured that all replacement players fitted the same maturity status threshold as the player they replaced. Before the commencement of the study, institutional ethics committee approval was

obtained, as well as informed, written consent from both the participants and their parents/guardians.

Anthropometric and maturity measures

Practitioners employed by each club collected stature, seated stature, and body-mass using previously published methods (see Towlson et al., 2017, 2018) as part of routine assessment within the academy and shared the data with the lead researcher for the present study. All measurements were taken within one week of initial club visits. Maturity status was estimated using the Fransen method (Fransen et al., 2018). Age at peak height velocity (APHV) and maturity offset (MO) were then derived from the maturity ratio.

Experimental design

Using a similar previously published approach to bio-banding (Lüdin et al. 2021), players were ranked based on their maturity offset (MO) and split at the median (−1.1 years) to create a biologically more mature group (−1.0 to +1.2 years) and a biologically less mature group (−1.1 to −2.6 years). Both groups were significantly different from each other in stature, mass and MO ($p < 0.001$). This present study randomly assigned players to one of four teams for bio-banded competition – More Mature A or B and Less Mature A or B. Mixed maturity teams consisting of more and less mature players were also created. Players were randomly assigned to either mixed maturity A, B, C or D with teams comprising of an even amount of more and less mature players except for 5v5 where Mixed Maturity A and B consisted of three more mature and two less mature players while Mixed Maturity C and D teams consisted of two more mature and three less mature players. Mixed maturity teams aimed to reflect the current composition of academy teams within youth soccer and acted as a surrogate control group. Bio-banded and Mixed games were completed in a round-robin style tournament resulting in six Bio-banded and six Mixed matches, which created three game types – Maturity Matched (More vs More, Less vs Less), Maturity Mismatched (More vs Less) and Mixed Maturity (see Appendix 1). This format was conducted at each academy one evening per week for three consecutive weeks, resulting in 72 small-sided games being played. Each week the number of players per team increased: Week 1) 4v4; Week 2) 5v5: and Week 3) 6v6. The team and subsequent pitch size were selected due to the availability of players to make up the teams – particularly given the difficulties of trying to create groups of less mature players within academy settings. Whilst the number of players increased, a fixed relative pitch size of 141 m^2 per player was used. This specific relative pitch size was derived from the current minimum Scottish Football Association guidelines regarding the pitch dimensions for a 7-a-side match (55 m × 36 m). For example, the pitch area for 7v7 is (55 × 36) 1980 m^2, so the area per player is (1980 ÷ 14) 141 m^2. Therefore, 4v4 pitch size was obtained using the following method: Required pitch area is (141 × 8) 1128 m^2, so dimensions are 40.3 m × 28 m (40.3 × 28 = 1128.4), resulting in an area per player of 141.05 m^2 (1128.4 ÷ 8). The same method was used to obtain the pitch dimensions of 5v5 (44.1 m × 32 m) and 6v6 (47 m × 36 m). Like previous research (Towlson, Abt et al, 2021; Towlson, MacMaster et al, 2021; Towlson, Salter et al, 2021), each small-sided game was five minutes in duration. At any one time, only two teams were competing in a small-sided game whilst the other two teams were playing soccer tennis to ensure the activity of players not competing was standardised throughout the study. There was a five-minute washout period between the bio-banded and mixed maturity matches, during which players were allowed to rest and recover - for example, by rehydrating or visiting the bathroom, where necessary. Each small-sided game was conducted on a 3-G synthetic surface with two mini goals (2 m × 1 m) placed at the midpoint of each end on the field. No goalkeepers were allowed in this present study, and players were restricted from scoring until they were in the opposing team's half. A multi-ball system was used to keep the game flowing, with footballs placed outside the perimeter of the pitch. Unless communicating a refereeing decision or the score line, coaches and researchers were restricted from interacting with players to control for the effects of verbal feedback or encouragement. Additionally, players were not given any instruction regarding playing position during any games.

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Inertial measurement units

Locomotor activities, Technical actions and individual possession staistics were quantified using commercially available foot-mounted IMUs (PlayerMaker™, Tel Aviv, Israel). Each IMU incorporated two components from the MPU-9150 multi-chip motion tracking module (InvenSense, California, USA), being a 16 g triaxial accelerometer and a 2000°•sec^{-1} triaxial gyroscope. Housed in manufacturer-supplied tightly fitting silicone straps, each player was equipped with two IMUs (one for each foot), which were located at the lateral malleoli over the player's boots. To diminish issues related to inter-unit reliability, players used the same IMUs throughout the data collection period (Buchheit et al., 2014; Malone et al., 2020).

All devices were activated via a Bluetooth connection to an iPad (Apple Inc, California) prior to each training session. Data was uploaded to the manufacturer's cloud-based software (v.3.22.0.02) post-session by the club practitioners. The start and end of each match was identified and tagged prior to data being exported from the manufacturer's cloud-based software into Microsoft Excel 2020.

Technical actions

Technical actions were defined as the number of releases, the number of touches, number of possessions and the total time on the ball (Players time on the ball is defined as the time between a player receiving the ball (start of their possession) to when a player releases the ball (end of their possession)) (Lewis et al., 2022; Marris et al., 2022), that a player had within a small-sided game, with footedness (a players use of their dominant vs. their non-dominant foot) also observed. Individual player possession statistics were monitored and defined as the time between a player receiving a ball and releasing the ball. This definition was used to quantify the total time a player spent on the ball within a game and their average time on the ball per an individual possession. While the number of touches and releases have been shown to be valid and reliable (Lewis et al., 2022; Marris et al., 2022), the time between a touch and a release have not yet been defined within the current literature. As such these reports are preliminary with recommendations made to assess the validity and reliability of these metrics against a criterion measure. However, the authors were unable to find an objective criterion measure for time on the ball.

Physical actions

The physical metrics analysed in the present study were total distance, high-intensity distance (>4 m/s/s), and number accelerations (>2 m/s/s) and decelerations (<-2 m/s/s). These metrics were selected as they have been shown previously to be indicative of successful performances in adolescent soccer (Towlson, MacMaster et al., 2021; Towlson, Salter et al., 2021).

Psychological scoring

Psychological data was collected using the valid and reliable Hull Soccer Behavioural Scoring Tool (Robinson et al., 2024), previously used by Towlson, MacMaster et al (2021). The chart consisted of four categories (Confidence, Competitiveness, X-factor and Positive Attitude), each representing a critical psychological characteristic for youth coaches and talent selectors when recruiting a player for talent identification programmes (Larkin et al., 2017; Towlson et al., 2019). Coaches from each participating club were provided with the scoring chart before the commencement of the testing session and assigned a team(s) they were responsible for scoring. Coaches were provided with a period to familiarise themselves with the scoring chart and offered the opportunity to ask any questions they felt were relevant before the testing sessions. Each scoring chart provided a definition of the specific psychological characteristics being assessed to provide the coaches with an understanding of what they were assessing. Assessors scored each desirable trait between 1 and 5 depending on their perception of a player's psychological performance during the small-sided games. Coaches were sometimes required to assess multiple players within a given match. They were instructed to leave a variable blank if they could not evaluate a player on a specific psychological trait. The criteria for scoring each of the psychological characteristics were as follows: 1 – poor, 2 – below average, 3 – average, 4 – very good and 5 – excellent. The player's scores for each variable were then accrued to provide an aggregate score out of 20 for each small-sided game. Whilst it is recognised that the psychological scoring chart has yet to be validated within an applied setting, it has been suggested that these measures likely possess a high level of ecological validity due to their reflection on current academy practices (Towlson et al, 2021b). However, it is acknowledged that the

tool has not been specifically validated in the context of bio-banded small-sided games, which may influence the interpretation of the results. This introduces a potential limitation, as the tool's subjective nature may affect the consistency of psychological scores.

Statistical analysis

Two-tailed statistical significance was accepted as $p \leq 0.05$ and measures of effect size were calculated using partial eta-squared (η^2). Magnitude of the effect sizes were *small* ($0.2 \leq ES < 0.6$), *moderate* ($0.6 \leq ES < 1.2$), *large* ($1.2 \leq ES < 2.0$) and *very large* (≥2.0). Data were analysed for normal distribution using Shapiro-Wilk and Kolmogorov-Smirnov tests. A one-way ANOVA was conducted to analyse the differences in technical and physical performance between teams sizes (4 v 4, 5 v 5, 6 v 6) and game formats (maturity matched, maturity mismatched, and mixed maturity). Post-hoc analyses were conducted using Tukey's test when the assumption of homogeneity of variances was met, as determined by Levene's test, and the Games-Howell test when this assumption was violated. This dual approach ensures that the statistical findings are both rigorous and appropriate for the data distribution. Differences between maturity groups (More mature and Less mature) were assessed using an Independent samples T-Test or Mann-Whitney U analyses for those data that were parametric or non-parametric, respectively. Due to the categorical nature of the psychological scoring chart, non-parametric tests were conducted. A Kruskal-Wallis test was used to analyse the effect of team size and game format, and a Mann-Whitney U test was conducted for the impact of maturity. All analyses were completed using the software IBM SPSS statistics (version 26; SPSS, IBM, Chicago, IL, USA).

Results

Technical actions

During maturity-matched games, technical actions (Table 1) decreased as team size increased from 4v4 to 6v6 games for both more and less mature groups. However, the analysis identified that team size had no significant effect on technical actions for both more mature (Touches (f): $p = 0.088$, ES = 0.00–0.70; Releases (f): $p = 0.12$, ES = 0.05–0.59; Possessions (f): $p = 0.143$, ES = 0.05–0.23; Time on the Ball (s): $p = 0.434$, ES = 0.07–0.37) and less mature players (Touches (f): $p = 0.054$, ES = 0.15–0.74; Releases (f): $p = 0.051$, ES = 0.13–0.80; Possessions (f): $p = 0.054$, ES = 0.20–0.65; Time on the Ball (s): $p = 0.19$, ES = 0.15–0.54) during maturity matched games.

Similarly, no significant differences were present between 4 vs 4, 5 vs 5 or 6 vs 6 maturity mismatched games for more mature players. However, it was found that team size had a significant effect on technical actions during maturity-mismatched games for less mature players (Touches (f): $p < 0.001$, ES = 0.31–0.92; Releases (f): $p < 0.001$, ES = 0.17–0.86; Possessions (f): $p < 0.001$, ES = 0.36–0.87; Time on the Ball (s): $p = 0.001$, ES = 0.40–0.88). Further analysis identified that during 4 vs 4 games, players had significantly more Touches (f) (24 ± 15 vs 13 ± 8, $p = 0.002$ (3.29–16.84), ES = 0.92), Releases (f) (8 ± 6 vs 5 ± 3, $p = 0.006$ (0.92–6.05), ES = 0.86), Possessions (f) (9 ± 6 vs 5 ± 3, $p = 0.003$ (1.12–6.34), ES = 0.87) and Time on the Ball (s) (15 ± 11.1 vs 7.6 ± 5.9, $p = 0.004$ (2.16–12.56), ES = 0.88) compared to 6 vs 6 games. Less mature players had significantly more Touches (f) (20 ± 9 vs 13 ± 8, $p = 0.003$ (1.96–10.82), ES = 0.76), Releases (f) (7 ± 4 vs 5 ± 3, $p = 0.001$ (0.96–4.41), ES = 0.84) and Possessions (f) (8 ± 4 vs 5 ± 3, $p = 0.001$ (1–4.53), ES = 0.36) during 5 vs 5 games than they did during 6 v 6 games. No significant differences were present between 4 vs 4 and 5 vs 5 games during maturity mismatched small-sided games ($p =$, ES = 0.17–0.49).

During mixed maturity matches, it was found that team size significantly affected the technical actions displayed by more mature and less mature players. Further analysis identified that more mature players had significantly greater technical actions during 4 vs 4 games compared to 6v6 games with regards to Touches (f) (22 ± 8 vs 17 ± 6, $p = 0.001$ (1.9–8.64), ES = 0.72, Releases (f) (8 ± 3 vs 6 ± 2, $p = 0.001$ (0.6–2.9), ES = 0.70, Possessions (f) (8 ± 3 vs 6 ± 2, $p = 0.001$ (0.67–2.97), ES = 0.59 and Time on the Ball (s) (14.4 ± 8 vs 10.2 ± 6.2, $p = 0.008$ (0.94–7.43), ES = 0.60). During 5 vs 5 games, there were also significantly more Touches (f) (21 ± 6 vs 17 ± 6, $p = 0.001$ (1.55–6.71), ES = 0.67), Releases (f) (7 ± 2 vs 6 ± 2, $p = 0.004$ (0.35–2.26), ES = 0.57), Possessions (f) (8 ± 2 vs 6 ± 2, $p = 0.007$ (0.28–2.17), ES = 0.56) and Time on the Ball (s) (14 ± 6.6 vs 10.3 ± 6.2, $p = 0.003$ (1.12–6.42), ES = 0.60) compared to 6 vs 6 games. During 4v4 games, less mature players took significantly more touches (f) than during 5 vs 5 games (22 ± 11 vs 17 ± 7, $p = 0.033$ (0.33–9.36), ES = 0.53). Similar to more mature players, less mature players exhibited significantly greater technical actions during 4 vs 4 games than they did during 6 vs 6 games with regards to Touches (f) (22 ± 11 vs 15 ± 7, $p = 0.001$ (2.82–11.62), ES = 0.78), Releases (f) (7 ± 4 vs 5 ± 2, $p = 0.007$ (0.5–3.71), ES = 0.64), Possessions (f) (8 ± 4 vs 5 ± 3, $p = 0.007$ (0.49–3.66), ES = 0.62) and Time on the Ball (s) (13.8 ± 8.8 vs 9.3 ± 6.4, $p = 0.009$ (0.98–8.01), ES = 0.58). No significant differences were found between 5 vs 5 and 6 vs 6 for less mature players ($p =$, ES = 0.19–0.33).

During maturity matched format, it was found that more mature players had significantly greater Releases (f) (8 ± 3 vs 5 ± 3, $p = 0.018$, ES = 0.69) and Possessions (f) (8 ± 3 vs 6 ± 3, $p = 0.025$,

Table 1. Summary of key metrics and definitions.

Metric	Definition	Method of Measurement	Example Metrics
Technical Actions	Quantifiable player interactions with the ball.	Foot-mounted inertial measurement units (IMUs).	Touches, releases, possessions, time on the ball.
Physical Actions	Metrics reflecting players' movement and intensity during games.	Foot-mounted inertial measurement units (IMUs).	Total distance, high-intensity distance (>4 m/s^2), accelerations, decelerations.
Psychological Characteristics	Subjective assessments of player behaviours and traits during games.	Hull Soccer Behavioural Scoring Tool (coach assessments).	Confidence, competitiveness, positive attitude, X-factor.

ES = 0.42) than less mature players during 6 vs 6 match play. No other significant differences were present between more and less mature players during maturity-matched 4 vs 4, 5 vs 5 and 6 vs 6 games (p =, ES = 0.06–0.37).

In 4 vs 4 and 5 vs 5 match-play during the maturity mismatched format, no significant differences were present between the technical characteristics of more and less mature players. More mature players had significantly more Touches (f) (20 ± 7 vs 13 ± 8, $p < 0.001$, ES = 0.86), Releases (f) (8 ± 3 vs 5 ± 3, $p < 0.001$, ES = 1.22), Possessions (f) (8 ± 3 vs 5 ± 3, $p < 0.001$, ES = 0.87) and Time on the ball (s) (12.4 ± 5.8 vs 7.6 ± 5.9, $p < 0.001$, ES = 0.81) during 6 vs 6 maturity mismatched games than less mature players. During mixed maturity format, significant differences were present between more and less mature players during 5 vs 5 match play, with more mature players having significantly more Touches (f) (21 ± 6 vs 17 ± 7, $p = 0.005$, ES = 0.48), Releases (f) (7 ± 2 vs 6 ± 3, $p = 0.001$, ES = 0.57), Possessions (f) (8 ± 2 vs 6 ± 3, $p < 0.001$, ES = 0.38) and Time on the Ball (s) (14 ± 6.6 vs 10.7 ± 6.4, $p = 0.005$, ES = 0.53). More mature players also had significantly greater Possessions (f) during 6 v 6 match play than less mature players (6 ± 2 vs 5 ± 3, $p = 0.037$, ES = 0.11).

Physical actions

In the 6 vs 6 mismatched ($p = 0.041$, ES = 0.68) and matched ($p = 0.006$, ES = 0.73) games, the more mature soccer players covered a significantly greater total high intensity distance (m) than less mature soccer players. The effects on total distance (m) appeared to also be influenced by the game type as within the mixed game format ($p = 0.013$, ES = 0.05) the less mature players covered a significantly greater total distance (m) than more mature players, however within the matched ($p = 0.006$, ES = 0.51) game format the more mature soccer players covered a greater total distance (m).

Maturity mismatched games appeared to have an affect on the physical output of the two groups as the more mature soccer players covered significantly greater high-intensity distance (m) ($p = 0.041$, ES = 0.06) than less mature players. All of the effects in mismatched games occurred within the 6 vs 6 team and relative pitch size. The matched game format also had an effect on physical output, as the more mature players performed a significantly greater total high intensity distance (m) ($p = 0.009$, ES = 0.73) than less mature soccer players during 6 vs 6 games.The only effect that saw the less mature goup perform more than the more mature group was within the Mixed 6 vs 6 game which saw them perform a significantly ($p = 0.003$, ES = 0.05) greater total distance (m) (see Table 2).

Psychological scoring

During maturity-matched games, more mature players displayed significantly greater psychological characteristics (Table 3) during 4 vs 4 games compared to 5 vs 5 (12 ± 3 vs 9 ± 5, $p = 0.045$, ES = 0.15–0.68) and 6 vs 6 (12 ± 3 vs 8 ± 4, $p = 0.02$, ES = 0.44–1.01) games. No significant difference was present between 5v5 and 6v6 for more mature players ($p = 0.283$). In contrast to the more mature cohort, less mature players displayed similar psychological characteristics across 4 vs 4, 5 vs 5 and 6 vs 6 games with no significant differences present ($p = 0.098$, ES = 0.1–1.00).

Maturity-mismatched games produced a similar trend to maturity-matched games concerning the psychological characteristics displayed by more and less mature players. During 4 vs 4 games, more mature players showed significantly greater psychological characteristics compared to 5 vs 5 (14 ± 2 vs 9 ± 4, $p < 0.001$, ES = 0.20–0.43) and 6 vs 6 (14 ± 2 vs 8 ± 5, $p < 0.001$, ES = 0.62–1.26) games. No significant difference was present between 5 vs 5 and 6 vs 6 games ($p = 0.569$, ES = 0.34–0.96). Less mature players displayed consistent psychological characteristics across 4 vs 4, 5 vs 5 and 6 vs 6 games with no significant differences present as team size increased ($p = 0.498$, ES = 0.00–0.45; Table 4).

Mixed maturity games elicited significantly greater psychological characteristics for more mature players during 4 vs 4 compared to 5 vs 5 (12 ± 5 vs 11 ± 4, $p = 0.042$, ES = 0.1–0.29) and 6 v 6 (12 ± 5 vs 10 ± 5, $p = 0.022$, ES = 0.17–0.58) games. No significant difference was present between 5 vs 5 and 6 vs 6 games ($p = 0.852$, ES = 0.05–0.50). In contrast to maturity matched and mismatched, less mature players displayed significantly greater psychological characteristics during 4v4 mixed maturity small-sided games compared to 5 vs 5 (13 ± 4 vs 10 ± 4, $p < 0.001$, ES

Table 2. Descriptive data showing technical output for more and less mature players during different game formats and team sizes.

	Maturity Matched			Maturity Mismatched			Mixed Maturity		
Technical Metric	4v4	5v5	6v6	4v4	5v5	6v6	4v4	5v5	6v6
More Mature									
Touches (n)	25 ± 12	19 ± 5	19 ± 8	20 ± 8	19 ± 9	20 ± 7	22 ± 8	21 ± 6	17 ± 6
Recieves (n)	7 ± 4	6 ± 2	6 ± 3	6 ± 3	5 ± 3	6 ± 3	6 ± 3	6 ± 2	4 ±
Releases (n)	10 ± 5	7 ± 3	8 ± 3	8 ± 4	7 ± 3	8 ± 3	8 ± 3	7 ± 2	6 ± 2
Possession (n)	10 ± 5	8 ± 3	8 ± 3	8 ± 4	7 ± 3	8 ± 3	8 ± 3	8 ± 2	6 ± 2
Time on the ball (sec)	14.8 ± 9.4	12.2 ± 5.9	11.7 ± 7.4	12.3 ± 6.2	12.4 ± 8.9	12.4 ± 5.8	14.4 ± 8	14 ± 6.6	10.3 ± 6.2
Time on the Ball per Possession (s)	2.2 ± 1	2 ± 0.6	1.9 ± 0.6	2.2 ± 0.5	2.2 ± 1	2.1 ± 0.7	2.5 ± 0.9	2.4 ± 0.8	2.3 ± 0.9
Less Mature									
Touches (n)	23 ± 14	22 ± 8	16 ± 9	24 ± 15	20 ± 9	13 ± 8	22 ± 11	17 ± 7	15 ± 7
Recieves (n)	6 ± 5	6 ± 3	5 ± 3	7 ± 5	5 ± 3	4 ± 2	6 ± 3	5 ± 2	4 ± 2
Releases (n)	8 ± 6	8 ± 3	5 ± 3	8 ± 6	7 ± 4	5 ± 3	7 ± 4	6 ± 3	5 ± 2
Possession (n)	8 ± 6	8 ± 3	6 ± 3	9 ± 6	8 ± 4	5 ± 3	8 ± 4	6 ± 3	5 ± 3
Time on the Ball (sec)	14.1 ± 11.6	12.8 ± 7.1	9.5 ± 6.1	15 ± 11.1	11.2 ± 8.5	7.6 ± 5.9	13.8 ± 8.8	10.7 ± 6.4	9.3 ± 6.4
Time on the Ball per Possession (s)	2.3 ± 0.8	2 ± 0.6	2.1 ± 0.7	2.2 ± 0.7	2 ± 0.7	2.2 ± 0.9	2.3 ± 0.7	2.1 ± 0.8	2.2 ± 0.9

Table 3. Descriptive data showing physical output for more and less mature players during different game formats and team sizes.

	Maturity Mismatched			Maturity Mixed			Maturity Matched		
Physical Metric	4V4	5V5	6V6	4V4	5V5	6V6	4V4	5V5	6V6
More Mature									
HI Distance (m)	63.97 ± 35.11	64.15 ± 35.42	43.31 ± 32.81	67.27 ± 42.71	60.45 ± 35.56	54.07 ± 34.29	71.88 ± 35.83	64.30 ± 31.21	34.29 ± 22.64
Total Distance (m)	568.41 ± 101.70	571.30 ± 71.04	542.44 ± 77.95	569.02 ± 65.13	552.47 ± 64.83	529.79 ± 69.92	694.88 ± 46.59	587.50 ± 65.63	513.17 ± 79.13
Intense Speed Changes (#)	5 ± 3	5 ± 2	4 ± 3	14 ± 9	11 ± 6	9 ± 6	5 ± 3	6 ± 3	3 ± 2
Less Mature									
HI Distance (m)	86.66 ± 32.79	80.22 ± 32.43	65.52 ± 31.33	81.67 ± 36.37	75.25 ± 30.92	68.99 ± 38.30	78.69 ± 23.54	80.55 ± 40.44	50.50 ± 29.71
Total Distance (m)	567.97 ± 48.68	563.95 ± 57.80	537.71 ± 62.28	551.54 ± 55.27	562.57 ± 59.86	525.99 ± 98.14	603.19 ± 55.28	585.45 ± 55.44	552.38 ± 63.30
Intense Speed Changes (#)	7 ± 4	7 ± 3	6 ± 3	6 ± 3	14 ± 7	10 ± 6	6 ± 4	6 ± 3	5 ± 2

Table 4. Descriptive data showing psychological output for more and less mature players during different game formats and team sizes.

	Maturity Matched			Maturity Mismatched			Mixed Maturity		
Metric	4v4	5v5	6v6	4v4	5v5	6v6	4v4	5v5	6v6
More Mature Psych Agg Score	12 ± 3	9 ± 5	8 ± 4	14 ± 2	9 ± 4	8 ± 5	12 ± 5	11 ± 4	10 ± 5
Less Mature Psych Agg Score	12 ± 6	12 ± 2	13 ± 4	11 ± 5	11 ± 4	12 ± 4	13 ± 4	10 ± 4	11 ± 5

= 0.02–0.59) and 6 vs 6 (13 ± 4 vs 11 ± 5, $p = 0.004$, ES = 0.10-–0.38) mixed maturity small-sided games. There was no significant difference present between 5 vs 5 and 6 vs 6 mixed maturity small-sided games for less mature players ($p = 0.156$, ES = 0.11–0.46).

Less mature players exhibited significantly greater psychological characteristics during 5 vs 5 (12 ± 2 vs 9 ± 5, $p = 0.019$, ES = 0.08–0.83) and 6 vs 6 (13 ± 4 vs 8 ± 4, $p < 0.001$, ES = 1.38-–1.75) maturity-matched games compared to more mature players. More mature players displayed significantly greater psychological characteristics during maturity mismatched format during 4 vs 4 (14 ± 2 vs 11 ± 5, $p = 0.004$, ES = 0.11–0.72) compared to less mature players. Whilst not significant, less mature players displayed greater psychological characteristics (11 ± 4 vs 9 ± 4) on average during 5 vs 5 mixed maturity games, and significantly greater psychological characteristics during 6v6 mixed maturity games (12 ± 4 vs 8 ± 5, $p = 0.001$, ES = 0.09–0.42) compared to more mature players.

Discussion

Although strong evidence exists to advocate the application of bio-banding during small-sided games (Abbott et al., 2019; Bradley et al., 2019; Hill et al., 2020; Lüdin et al., 2021; Towlson et al., 2023), only Towlson, MacMaster et al. (2021) have examined the effect of game constraint (relative pitch size) manipulation on its efficacy. Therefore, to better understand the influence of key game constraints on the efficacy of bio-banded small-sided games, this study examined the effect of maturity-matched and miss-matched bio-banding on important technical, tactical, physical and psychological player performance metrics during small-sided games when contested by teams comprised of a different number of players (4v4, 5v5 and 6v6), whilst controlling for relative pitch size. The primary findings of the study were, 1) During maturity-matched games, as team size increased from 4 vs 4 to 6 vs 6 games, small to moderate reductions in technical actions were observed. This was evident for both more and less maturity groups; 2) Technical (e.g. touches, releases, possessions and time on the ball) and physical (e.g. high intensity distance) differences were observed between less and more mature players during 6 vs 6 maturity mismatched small-sided game formats. However, such differences did not not manifest during 4 vs 4 and 5 vs 5 formats; 3) During maturity-matched and mixed maturity game formats, more mature players displayed small to moderate increases in psychological characteristics during 4 vs 4 games compared to other game formats.

The typical purpose of maturity matched bio-banded soccer formats are to create an equitable playing environment (Cumming et al., 2017; Malina et al., 2019; Towlson, Cumming, et al., 2022), which is devoid of recipient players possessing temporary, maturity-related (physical (Lovell et al., 2015; Towlson et al., 2017), anthropometric (Towlson et al., 2018), technical-tactical (Gonçalves et al., 2021) and psychological (Cumming et al., 2018; Towlson, Salter et al., 2021)) (dis)advantages which are considered important during talent identification (Larkin et al., 2017; Towlson et al., 2019), and can influence individual match-play responses during mixed maturity match-play and training (Cumming et al., 2018; da Costa et al., 2023; Lovell et al., 2019). This is a particularly important phenomena to consider, given that academy soccer practitioners are likely to (de)select players based on greater emphasis on specialist physical/technical position-specific attributes as players navigate the development pathway towards professional status (Towlson et al., 2019). As the present study showed, technical actions reduced, as the number of players increased on the pitch, practitioners and talent ID staff should be aware of this

within their recruitment protocols. An increased number of players may reduce the players opportunities to showcase their technical ability within games for this particular age band of player. Despite these findings, previous research has shown strong correlations between the technical outcomes of 9v9 games compared to coaches/scouts' opinion on players being successful during these talent ID type events for U11's (King et al., 2024). Further research is warranted to understand that if the outcomes of the games utilised in the current study translate to the outcomes of players being successful or unsuccessful during talent ID type activities.

Bio-banding has been shown to influence technical characteristics of players (Abbott et al., 2019; Lüdin et al., 2021). Towlson, MacMaster, Gonçalves et al. (2022) showed that tactical characteristics such as the distance to nearest opponent and distance to centroid observed during maturity matched fixtures for post-PHV players may increase. With the authors postulating that this was a result of the post -PHV players being characterised as possessing advanced, and reduced group variation in maturity-related characteristics such as stature, strength and speed (Bolckmans et al., 2022; Helsen et al., 2021; MacMaster et al., 2021), all of which being important components for soccer player technical development and match actions (e.g. passes, dribbles, shots etc). As such the individual advanced lower limb strength of 'earlier' maturing players (Lloyd et al., 2015), developed with specific strength and athletic development programmes spanning PHV (Peña-González et al., 2019) likely enhances post-PHV strength and power to propel the ball longer distances and subsequently decrease the number of individual technical actions required to achieve the same tactical outcome. Therefore, if measures of technical performance are a primary key performance indicator during talent identification, evidence here suggests that using smaller numbers of less mature players will likely elicit more technical actions being performed. Furthermore, the relationship between positioning variables such as distance to the nearest opponent and centroid and technical performance is critical to understanding how spatial dynamics influence individual and team actions during matchplay. Greater distance to the nearest opponent provides players with more time and space, facilitating more accurate and deliberate execution of technical skills such as passes, dribbles, and shots. Conversely, reduced distance to the nearest opponent, often observed in maturity-matched and smaller-sided games, challenges players to make quicker decisions and execute technical actions under pressure. Previous research (e.g. Towlson, MacMaster, Gonçalves et al., 2022; Gonçalves et al., 2021) indicates that post-PHV players may leverage their superior strength and speed to maintain advantageous positioning, reducing the variability in these variables and enabling a more effective application of technical skills. However, in maturity-matched games, particularly in smaller-sided formats, this advantage is less pronounced, and technical performance becomes more dependent on intrinsic skill and decision-making rather than physical dominance.

In addition to technical and tactical components of player performance, psycho-social behaviours of players during soccer performance are becoming increasingly more important to practitioners who assess talent (Larkin et al., 2017; Towlson et al., 2019). During maturity-matched games, this study showed that more mature players displayed small to moderate increases in psychological characteristics during 4v4 games in comparison to other game formats, whilst mixed maturity small-sided games elicited significantly greater psychological characteristics for more mature players during 4v4 compared other formats. These findings somewhat complement previous research which have found that maturity-matched biobanding may have a limited influence on physical variables on all players (regardless of maturation status), while enhancing a number of psychological variables considered key for talent identification in pre-PHV (Towlson, MacMaster et al., 2021). Previous findings suggest that more mature players, who are characterised as having a temporrary maturity-related enhanced athropomertric, physical and decision making characteristics (Figueiredo et al., 2009; Gonçalves et al., 2021; Lovell et al., 2015; MacMaster et al., 2021; Towlson et al., 2017) will likely possess transient performance advantages over their less mature counterparts. Subsequently, providing a more challenging playing environment for their later maturing counterparts to compete in. These challenging playing conditions ultimately provide less mature players with an opportunity to play in conditions that allow them to demonstrate a number of enhanced highly-desirable psychological characteristics (problem solving, resilience, leadership) which may partly be explained by the 'underdog hypothesis' (see (Cumming et al., 2018)). This theory postulates that later maturing players will have developed superior psychological skills that enable them to compete with their more mature counterparts on absolute terms (Gibbs et al., 2012). Suggesting that later maturing players (i.e. pre-PHV) will likely develop advanced self-regulatory skills, which represents the extent to which individuals are metacognitively, motivationally, and behaviourally proactive participants in their learning process (Zimmerman, 2006). This playing dynamic within mixed maturity (i.e. normal chronological age playing environments) may well thwart early maturing players' natural need to express such key psycho-social behaviours as they can depend on other strengths (advances height, weight, power, speed etc) to succeed. However, when faced with players of equal height, strength, power and speed (i.e. maturity matched), such players can no longer succeed using anthropometric, technical, tactical and physical characteristics alone, thus, they may be forced to implement key psycho-social behaviours as demonstrated within the present study.

Practical implications

Smaller team sizes (e.g. 4v4) were shown to moderately increase the frequency of technical actions such as touches, releases, and possessions. The 4v4 format provided more opportunities for individual player engagement with the ball, as indicated by the higher frequency of technical actions (e.g. touches, releases, possessions). The reduced number of players increased space and time available, allowing creativity and decision-making, especially for less mature players. It also

encouraged the display of psychological characteristics like confidence and competitiveness due to increased individual responsibility. Coaches should incorporate more small-sided games with fewer players into training sessions to create an environment where players have more opportunities to engage with the ball. The 4v4 format also encourages greater involvement from all players, fostering a more inclusive and engaging training experience.

With regards to the 5v5 format, this intermediate format balanced the density of players with the opportunity for technical and physical actions. While the frequency of technical actions decreased compared to 4v4, it allowed players to adapt to moderately increased game complexity, which could potentially serve as a transition between the smaller-sided and larger-sided formats. The 6v6 format introduced greater complexity, with more players sharing the same relative pitch size. This setup reduced the frequency of individual technical actions. Notably, in the 6v6 format, more mature players demonstrated their physical and technical advantages (e.g. greater high-intensity distance covered and more technical actions during mismatched games), highlighting how physical attributes begin to dominate as team and pitch size increase. The present study also found that smaller team sizes and maturity-matched games positively impact psychological characteristics such as confidence, competitiveness, and positive attitude, particularly for more mature players. Practitioners should design training programmes that consider the varying physical, technical, and psychological needs of players at different maturity stages. Regular assessments of players' maturity status can inform more personalised training interventions, ensuring that each player receives the appropriate level of challenge and support.

While this study provides valuable insights into the immediate effects of bio-banding and team size on technical, physical, and psychological performance, its cross-sectional design limits the ability to assess long-term developmental impacts. Longitudinal studies are needed to explore how these training modifications influence player development over time, particularly in relation to skill acquisition, psychological resilience, and progression through talent identification pathways. Future research could also investigate whether repeated exposure to bio-banded small-sided games leads to sustained benefits in performance and equitable talent identification. Additionally, exploring how these findings translate across different age groups, competitive levels, and cultural contexts would help to generalise the applicability of these training strategies. Such studies would provide a more comprehensive understanding of the developmental impacts of these interventions.

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Appendix 1

Details	N = 16 Week 1 (4 Vs 4) Pitch Dimension: 40.3 m × 28 m	N = 20 (Week 1 players + 4 new players) Week 2 (5 Vs 5) Pitch Dimension: 44.1 m × 32 m	N = 24 (Week 2 players + 4 new players) Week 3 (6 Vs 6) Pitch Dimension: 47 m × 36 m
Bio-Banded	Less A Vs Less B	Less A Vs Less B	Less A Vs Less B
	More A Vs More B	More A Vs More B	More A Vs More B
	Less B Vs More A	Less B Vs More A	Less B Vs More A
	More A Vs Less A	More A Vs Less A	More A Vs Less A
	Less B Vs More B	Less B Vs More B	Less B Vs More B
	Less A Vs More B	Less A Vs More B	Less A Vs More B
6 matches per player, 30 minutes total playing time			
***** 5-minute wash out period *****			
Mixed Maturity	Mixed A Vs Mixed B	Mixed A Vs Mixed B	Mixed A Vs Mixed B
	Mixed C Vs Mixed D	Mixed A Vs Mixed B	Mixed A Vs Mixed B
	Mixed B Vs Mixed C	Mixed B Vs Mixed A	Mixed B Vs Mixed A
	Mixed D Vs Mixed A	Mixed B Vs Mixed A	Mixed B Vs Mixed A
	Mixed B Vs Mixed D	Mixed B Vs Mixed B	Mixed B Vs Mixed B
	Mixed A Vs Mixed D	Mixed A Vs Mixed C	Mixed A Vs Mixed C
6 matches per player, 30 minutes total playing time			