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Role of maturation on small-sided games in youth soccer: a scoping review

review paper
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ABSTRACT
Purpose. The role of maturation in small-sided games (SSGs) has become a growing research focus. This study conducts a scoping review to map the evolution of research on the role of maturation in SSGs and synthesise its impact on physiological, physical, technical, and tactical parameters in youth soccer.
Methods. Online databases (PubMed, Web of Science, SportDiscus, and Scopus) were searched for articles from their inception until October 2024. Studies were selected based on the following criteria: (I) youth soccer players (< 18 years), (II) examining the influence of maturation on physiological, physical, technical, and tactical parameters, (III) conducting a qualitative or quantitative analysis of performance parameters, and (IV) employing observational or experimental studies. Study and SSG characteristics were synthesised narratively, while performance measures were presented in tabular format.
Results. 3 vs 3 (21%) and 4 vs 4 (29%) were the most frequently implemented SSG formats. The majority (96%) used a cross-sectional design, with over half (57%) incorporating players from professional soccer academies. The majority of the maturational effects were observed in technical parameters (33%) (e.g., passes), while physiological (e.g., heart rate, rating of perceived exertion), physical (e.g., accelerations), and tactical (e.g., pitch dispersion) parameters showed changes in 22% of the included studies.
Conclusions. This review highlights the impact of maturation on performance outcomes in SSGs, with technical parameters showing the strongest effects. Future research would benefit from a more careful selection of rigorous protocols and prospective studies. More studies investigating the influence of maturation in SSGs are required to provide guidance for practitioners in the field of youth soccer.
Key words: small-sided games, maturation, youth soccer, performance parameters, review

Introduction

Small-sided games (SSGs) are widely acknowledged as a pivotal training tool in youth soccer, offering a multitude of benefits for developing several performance dimensions [1–3]. The extant literature identifies a range of constraints employed in SSGs that have been demonstrated to influence physiological responses, physical outputs, technical actions, and tactical behaviours in youth soccer players [4–7]. More precisely, physiological variables, including heart rate (HR) measures (e.g., HR_{max}, HR_{mean}, %HR, modified Training Impulse), blood lactate levels, and perceived exertion (e.g., RPE, exertion index), vary under different SSG conditions (e.g., pitch area, player numbers, touch restrictions) [7–9]. This is reflected in physical measures such as total distance, distance covered in different velocity zones (e.g., running, high-speed running, very high-speed running, sprinting), number of sprints, accelerative and decelerative actions, or body loads/impacts [9, 10]. A variety of contextual variables (e.g., player numbers, relative area per player) has been shown to influence technical parameters (e.g., passes, receptions, contacts, dribbles, shots) [4, 10]. Regarding tactical performance, studies have examined relationships between outcomes like ball possession (e.g., duration), collec-

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tive dynamics (e.g., team length/width, spatial dispersion, inter-team index), and tactical actions (e.g., penetration, balance) under varying SSG configurations (e.g., implementation of floaters, age groups, expertise levels) [5, 9]. In this context, the scientific literature identifies maturation as a confounding factor, with reviews emphasising its critical role in shaping performance outcomes during SSGs [11].

Maturation (i.e., the progress towards the biologically mature state) [12] has become an important consideration in the developmental trajectories in youth soccer players [13]. The timing (i.e., onset of change), tempo (i.e., rate of change), and level (i.e., magnitude of change) of maturation is shaped by diverse and interrelated factors, which can result in alterations regarding motor coordination, physical capabilities, and technical skills [14]. These changes have been corroborated by systematic reviews indicating that maturation serves as a covariate in the development of motor performance within and between youth soccer players [15] and were also evident during official matches [16]. Specifically, early-maturing players cover greater total distance [17, 18], high speed running distance [18, 19] and sprint distance (TD) [20], achieve higher peak running speeds [20], and perform a greater number of high-intensity actions (e.g., decelerations, accelerations, tackles) [17, 21, 22]. In contrast, Lovell et al. [23] reported that late-maturing players covered greater distances at higher absolute speeds, indicating a divergent impact of maturation on intensive running performance. The influence of maturation on physical performance measures has been demonstrated in research on SSGs, both in maturity-matched (i.e., bio-banded) and non-bio-banded formats [24, 25]. In this context, divergent physiological responses, such as variations in RPE and HR metrics, have been observed in these formats [21, 26]. Specifically, bio-banded SSGs have been associated with reduced HR_{peak} and HR_{mean} [26], while only limited correlations between $\%HR_{max}$ and maturation have been reported in non-bio-banded SSGs [25, 27]. Early-maturing players exhibit higher session and differential RPE (e.g., breathlessness-related, technical/cognitive, leg exertion) in bio-banded SSGs, whereas late-maturing show elevated values in non-bio-banded SSGs [28, 29]. With regard to the technical and tactical aspects, research on non-bio-banded SSGs has yielded inconsistent findings. Studies have revealed associations between passing metrics and maturational groups. For example, early-maturing players have been observed to execute a greater number of passes, whereas players with delayed maturity status tend to perform more neutral ball actions [30, 31]. In bio-banded SSGs, Lüdin et al. [22] reported a higher frequency of attacking actions compared to non-bio-banded formats. However, other studies have demonstrated that bio-banding has a limited influence on technical and tactical variables across maturational groups [32].

Maturational influences on performance indicators in youth soccer players (e.g., strength capabilities, sprinting) have been consistently examined over the past decades [33–36]. However, to the authors' knowledge, the first study investigating its impact on SSGs was conducted in 2011 [27]. Since then, research on this topic has increased significantly, with approximately 65% of all studies being conducted since 2020 (based on a simple PubMed search using the terms 'small-sided games', 'youth soccer', and 'maturation'). Given the growing number of studies on the impact of maturation on SSGs in youth soccer across various performance domains, an overview of how existing research has been conducted remains unclear. This includes study designs, geographic and bibliographic characteristics, and the specific implementation of SSG formats. Furthermore, an in-depth analysis of maturational influences on physiological, physical, technical, and tactical parameters is still lacking. However, such information could be valuable for practitioners, considering the inter-individual differences in maturational processes among adolescent players [37]. Specifically, synthesising the existing literature on the interaction between these performance domains and maturation may support the implementation of individualised training strategies, enabling practitioners to optimise training designs and adopt a more comprehensive approach to training prescriptions.

In this context, systematic reviews or meta-analyses are often regarded as the gold standard in evidence synthesis, as they primarily include homogenous study designs (e.g., randomised controlled studies), providing strong confidence in the findings [38]. In the case of maturation's role in SSGs, the existing literature is still evolving, with studies varying in participant characteristics (e.g., gender, expertise levels), maturation assessment methods (e.g., invasive or non-invasive methods), and game characteristics (e.g., bio-banded or non-bio-banded). Given these challenges, a scoping review presents a more suitable approach, as it allows for a broad mapping of the current evidence, highlighting research gaps, and emerging trends [39]. Thus, a scoping review was deemed an appropriate method to address the research objectives [40]: (a) to map the current scientific landscape on maturation in SSGs, and (b) to synthesise current evidence regarding the role of maturation, specifically examining its effects on physiological, physical, technical, and tactical parameters in youth soccer players.

Material and methods

Protocol and registration

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) [39] and adheres to the Cochrane Handbook for Systematic Reviews of Interventions [41]. The review protocol was pre-registered on the Open Science Framework (OSF) on October 8th and last updated on December 12th, 2024 (identifier doi: 10.17605/OSF.IO/QRWXS).

Eligibility criteria

The eligibility criteria for this review were defined using the Population, Intervention, Comparator, Outcome and Study (PICOS) framework [42]. To be included in this review, studies needed to focus on youth soccer players under the age of 18 (P) and assess maturation while investigating its effects on physiological, physical, technical, and tactical parameters (I). Studies employing quantitative, qualitative, or mixed-method approaches were included to capture different aspects of measuring maturational effects (O). Furthermore, to maintain a broad perspective on the research objectives [43], peer-reviewed observational, cross-sectional, pilot, case studies, and experimental (non-)randomised controlled studies published in English from their first occurrence until the last search date (October 2024) were considered (S).

Studies were excluded if they did not examine youth soccer cohorts (e.g., adult players) or lacked sufficient information on maturational grouping, such as missing or unclear maturation estimation methods. Additionally, studies incorporating SSGs without analysing the effect of maturation on performance outcomes were excluded. Lastly, non-English publications and inappropriate publication formats (e.g., reviews or meta-analyses) were not considered.

Information sources and search

To identify potentially relevant documents, the following databases were searched from the earliest article available to October 2024: PubMed, Web of Science, SportDiscus, and Scopus. The electronic database search was supplemented by searching grey literature (https://opengrey.eu) and reference list screening of included studies, along with searches within previous reviews on similar topics. A primary search strategy was conducted by the first author in April 2024 and subsequently refined in collaboration with the contributing authors. The final literature search incorporated the following key terms as selected by the authors: 'small-sided games', 'soccer', 'football', 'matur*', and 'adol*'. A detailed version of the search terms and Boolean operators used in each database, along with the applied filters, is provided in the pre-registration form.

Selection of sources of evidence

The studies identified through the literature search were managed using Endnote (version 21.4, Clarivate, Philadelphia, PA, USA). Duplicate entries were removed before conducting a two-stage screening process. The first stage involved an independent screening of the titles and abstracts against predefined eligibility criteria, while the second stage comprised a full-text review of the remaining articles by two authors (i.e., JJ and MR). In cases of disagreement during the second stage, a third reviewer (i.e., ML) independently assessed the contested studies and facilitated discussions with the other reviewers until a consensus was achieved.

Data charting process and items

The data charting and extraction process was developed by two authors (i.e., JJ, MR) and was continuously refined through an iterative process until the final format was established, considering existing scoping reviews in the field of SSGs [44].

The extracted data from the eligible studies were systematically organised by the authors using a custom-designed table using Microsoft Excel (Version 2108, Microsoft, Redmond, WA, USA). In this standardised spreadsheet, reference data (i.e., author and year) and sample characteristics (i.e., sample size, age group, and playing level) were extracted. The study type was classified as cross-sectional if the investigation was conducted over a short time frame (e.g., a few weeks), whereas longitudinal designs encompassed studies conducted over extended periods (e.g., an entire season) [45]. Additionally, studies were categorised based on whether they employed a bio-banded game format (i.e., estimating maturity status while playing in maturity-matched fixtures) or a non-bio-banded game format (i.e., estimating maturity status without playing in maturity-matched fixtures). The criteria for the analysed game characteristics followed existing reviews [4], providing a compact overview of the SSGs employed, including playing format, pitch dimensions, area per player, regimen, and rules/conditions. Lastly, significant effects reported in the studies were extracted to summarise the existing evidence on the influence of maturation on performance dimensions.

Besides the data charting process of the included studies, VOSviewer (version 1.6.20, CWTS, Leiden, The Netherlands) and R Studio (Version 3.6, PBC, Boston, MA, USA) were used to map the scientific landscape, including the bibliographic coupling, co-authorship relations, and co-occurrence network of terms. This analysis aimed to provide insights into the geographic and bibliometric distributions as well as existing research groups addressing the study objectives [46].

Critical appraisal of individual sources of evidence

With regard to the objectives of scoping reviews – namely, mapping the existing literature and identifying key themes, trends, and knowledge gaps [43] – this review did not conduct a formal critical appraisal of individual sources of evidence, as recommended by Tricco et al. [39]. Since no methodological restrictions, such as controlling for confounders or sample size estimation, were applied during the study selection, a standardised critical evaluation was not conducted. However, methodological aspects were considered and discussed in a narrative manner.

Synthesis of results

For this scoping review, the results of the included studies were categorised as follows: (1) physiological (e.g., HR, RPE), (2) physical (e.g., total distance, accelerations/decelerations), (3) technical (e.g., passes, shots), and (4) tactical (e.g., attacking or defensive tactical principles, collective organisation measures) [10].

Results

Selection of sources of evidence

The literature search across all databases and cross-referencing yielded a total of 1,666 results. After removing ineligible articles prior to screening, such as duplicates and retracted articles, 1,311 articles remained for title and abstract screening. Following this step,

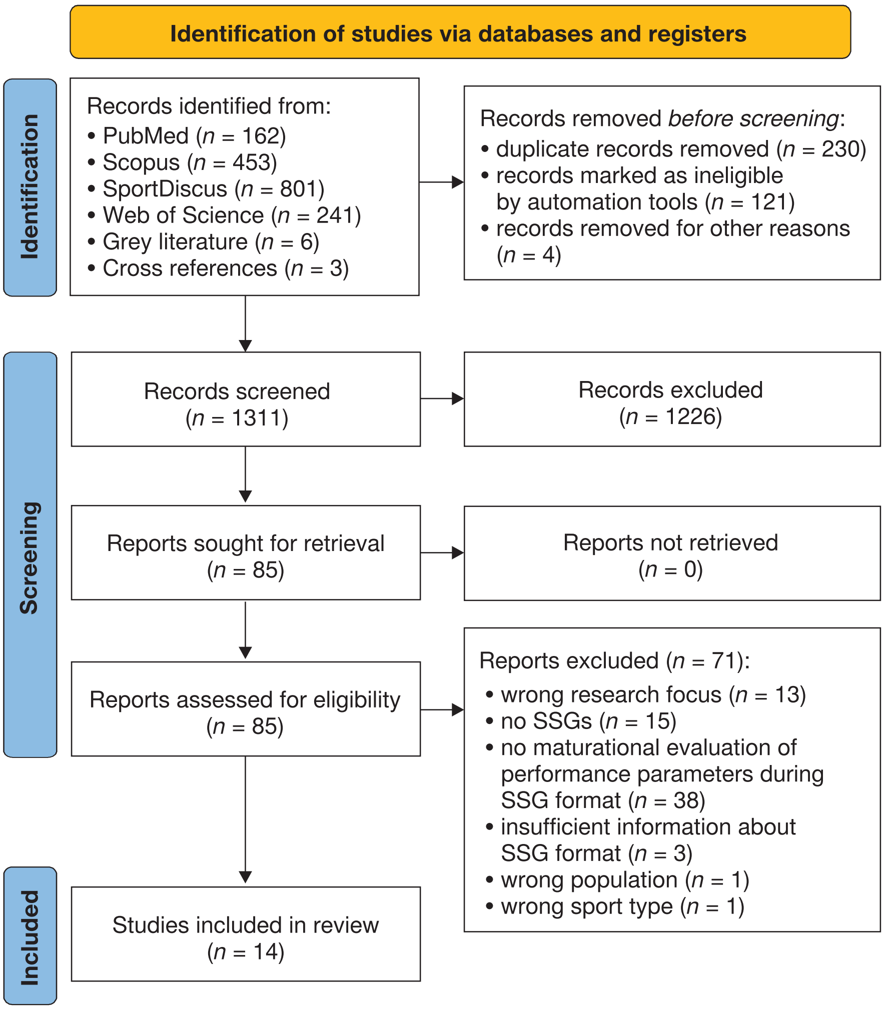


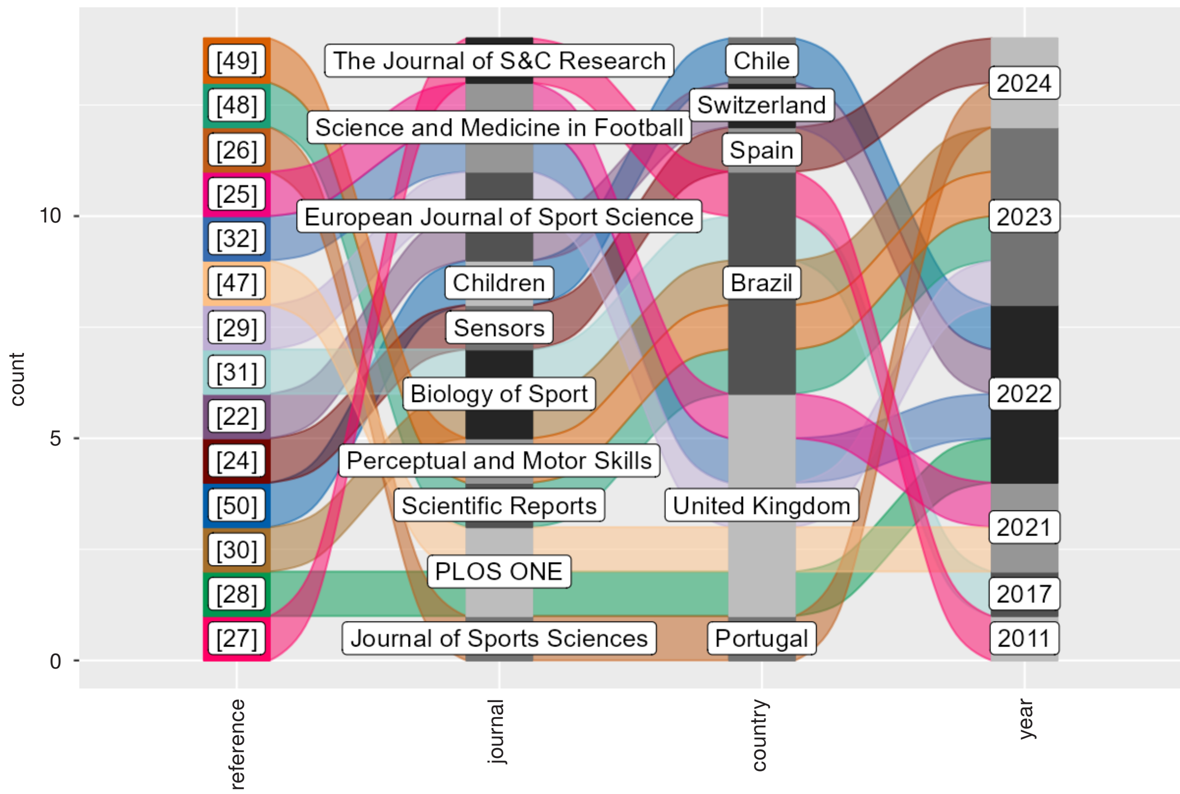
Figure 1. PRISMA flow chart

1,226 articles were excluded for not meeting the inclusion criteria. Subsequently, 85 articles underwent full-text assessment for eligibility. In the final phase, 71 articles were excluded for various reasons (detailed in Figure 1), resulting in a total of 14 studies included in the synthesis of results.

Characteristics of sources of evidence

A summary of the included studies is provided in Table 1. The review covered 771 subjects from U12 to U16, with a mean age of 14.0 ± 0.79 years. The sample size ranged from 12 to 116 participants (Table 1). Playing levels included professional youth academies (*n* = 8), state-level youth teams (*n* = 5), and recreational soccer schools (*n* = 1). Half the studies explored maturation's impact within bio-banded SSGs [22, 25, 26, 28, 29, 32, 47]. The remaining studies evaluated the maturity status of participants before SSG interventions in a non-bio-banded format [24, 27, 30, 31, 48–50].

All studies were peer-reviewed journal articles in English, primarily using a quantitative cross-sectional design. Data collection ranged from one [24, 49] to six [28] observational sessions, with most studies spanning two [22, 31], three [25, 29, 32], or four sessions [26, 30, 47, 48, 50]. One study collected data twice a week throughout a competitive season [27]. Eight studies were from Europe [22, 24–26, 28, 29, 32, 47], while six were from South America [27, 30, 31, 48–50] (for a detailed overview, see Figure 2). The mean number of authors per study was 7.64 (± 2.76) ranging from 4 [24] to 13 [32]. Since 2011, the number of records has steadily increased, with the highest publication output observed in 2023 and 2024 (both *n* = 4) (Figure 2). The co-authorship connections analysis (≥ 1 record) is displayed in Figure 3. The association strength analysis identified 10 clusters with 283 links and a cumulative link strength of 405. The most frequent contributors included Steve Barrett (*n* = 5), Christopher Towlson (*n* = 5), Ally Hamilton (*n* = 4), and Frances Hunter (*n* = 4) (Figure 3), while Christopher Towlson (21%) and Paulo Henrique Borges (14%) had the most first-authorships. Regarding journal distribution, the most common publication outlets were PLOS ONE, Biology of Sport, European Journal of Sport Science, and Science and Medicine in Football, each contributing two studies (14.3%) (Figure 2). The keyword co-occurrence analysis (≥ 3 occurrences) identified 45 key terms, with the most frequent being, 'bio-banding' and 'relationship' (both *n* = 6), followed by 'academy soccer players', 'biological maturation', 'maturity', 'height', and 'impact' (all *n* = 5).



S&C – strength and conditioning

Figure 2. Alluvial diagram illustrating the distribution of included journals, countries, and publication years

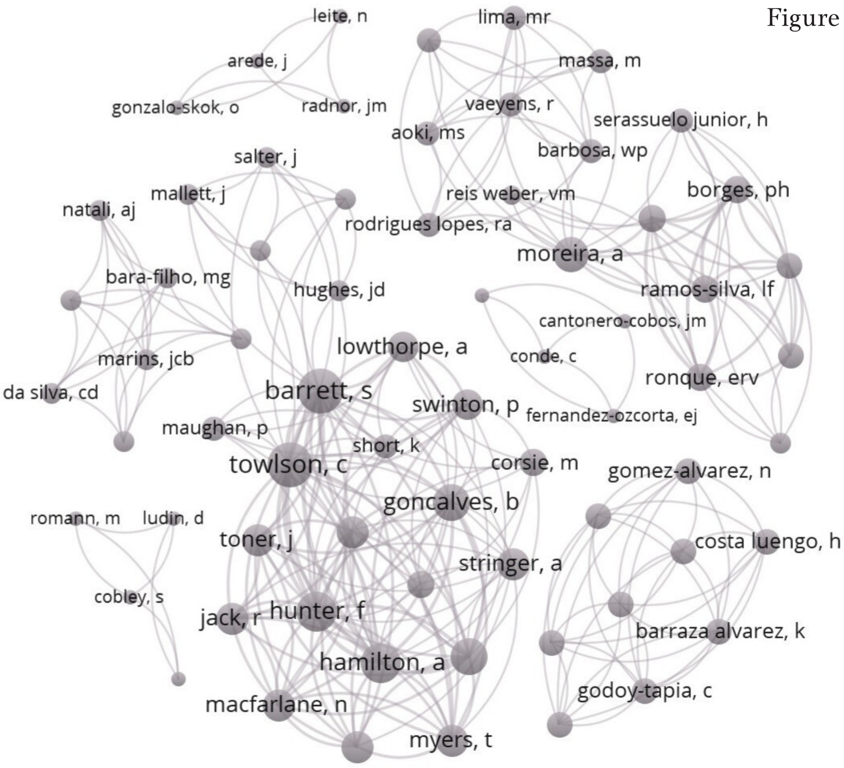


Figure 3. Authorships of articles published using VOSviewer

Regarding maturity estimates, nine studies used methods to estimate somatic maturity [22, 24–26, 28, 29, 32, 47, 50]. Three studies employed the Tanner-Whitehouse III protocol to assess skeletal age [30, 48, 49], while two studies utilised Tanner stages to estimate sexual maturity status [27, 31].

Small-sided game characteristics

The most common SSG formats were 3 vs 3 (21%) and 4 vs 4 (29%), with one study analysing maturation effects across 3 vs 3, 4 vs 4, and 5 vs 5 [27]. Additionally, the 5 vs 5, 6 vs 6, 7 vs 7, and 9 vs 9 formats were each represented in 7% of the studies, while one study did not specify the format [24]. Goalkeepers were included in six studies [22, 26, 29, 31, 48, 49]. Two studies adjusted the relative pitch size [47] or player numbers [27] due to specific research focuses. Pitch sized ranged from 25.5 to 276 m², (mean: 138 ± 75.0 m²). The mean number of playing sets was 3.50 ± 1.70 (range: 1–6), with an average duration of 8 min and 52 s ± 8 min and 59 s (range: 4–35 min). Active recovery between sets was implemented in 21% of the studies [25, 27, 32], passive recovery was utilised in 71% [22, 26, 28-31, 47–49], while one study [24] (8%) followed both an intermittent and continuous protocol without recovery periods.

Mean recovery time was 2 min and 52 s ± 2 min and 32 s (range: 1–10 min). Two studies reported a range for recovery time [25, 32]. Common constraints included a designated shooting zone within the attacking half of the pitch (*n* = 4), removal of goalkeepers (*n* = 4) and the use of reduced-size goals (*n* = 3). Further details on the specific rules and conditions across the included studies can be found in Table 1.

Synthesis of results

The results of the included data in this scoping review will be synthesised in a narrative manner in the following sections. For a concise mapping of the main evidence retrieved, please refer to Figure 4.

Effect of maturation on physiological parameters

Four studies [25, 26, 28, 29] investigated the effect of maturation on physiological parameters within bio-banded SSGs, whereas one study [27] focused on non-bio-banded SSGs. The majority were from the UK (*n* = 3) [25, 28, 29], while two originated from Portugal [26] and Brazil [27]. Four studies employed a cross-sectional design [25, 26, 28, 29], while one study reported results from a longitudinal analysis [27], all focusing on the examination of physiological parameters, including RPE metrics and HR measures. Barrett et al. [28] reported elevated differential ratings of perceived exertion (dRPE) in pre-PHV (peak height velocity) players during bio-banded SSGs and an increase in dRPE

Table 1. Study characteristics

Reference	Sample	Study type	Scope of study	Small-sided game characteristics					Main evidence about effects of maturation on performance parameters
				playing format	pitch dimensions (length × width)	area per player	regimen	rules/ conditions	
Arede et al. [26]	*n* = 116 U13–U14 13.3 ± 0.89 years (five Portuguese soccer academies)	cross-sectional bio-banded	to investigate differences in physiological, physical and tactical variables when competing in bio-banded versus non-bio-banded formats	7 vs 7 + GK	64 × 45 m	205.7 m^2 per player	1 × 20 min	– full-sized goals (6 × 2 m) – no verbal encouragement – positional allocation	↓ distance covered, decelerations, average speed, and body impacts (BB) ↓ HR_{peak} (BB)
Barrett et al. [28]	*n* = 32 U12–U14 12.9 ± 0.9 years (English professional soccer academies)	cross-sectional bio-banded	to investigate differences in different ratings of RPE in bio-banded versus non-bio-banded formats; examination of multivariate relationships between differen-tial RPE measures	4 vs 4	24 × 24 m	72 m^2 per player	6 × 5 min/ 3 min passive recovery	– two goals (2 × 1 m) – no GK – shooting zone within the attacking half of the pitch	↑ levels of sRPE, sRPE-B, sRPE-L, sRPE-T for pre-PHV (BB) ↑ overall levels of RPE during maturity (NBB)
Borges et al. [48]	*n* = 81 U13/U15 14.37 ± 1.12 years (Brazilian soccer teams at state level)	cross-sectional non-bio-banded	to explore the impact of maturation on players' roles within team dynamics and their decision-making	3 vs 3 + GK	36 × 27 m	162 m^2 per player	2 × 4 min/ 1 min passive recovery	official rules	↑ degree centrality for late-maturing players (NBB) ↑ degree of prestige for on-time maturing players (NBB) ↑ technical efficiency for late-maturing players (NBB)
Borges et al. [49]	U13 *n* = 24 12.89 ± 0.61 years U15 *n* = 57 14.96 ± 0.58 years (Brazilian soccer teams at state level)	cross-sectional non-bio-banded	to investigate the relationship between biological maturation, physical growth, and interaction-based centrality players	3 vs 3 + GK	36 × 27 m	162 m^2 per player	2 × 4 min/ 1 min passive recovery	official rules	↑ network-based centrality measures for U13 age group (NBB)
da Costa et al. [30]	U13 n = 24 12.9 ± n. a. years U15 *n* = 58 15 ± n. a. years (Brazilian soccer teams at state level)	cross-sectional non-bio-banded	to investigate how body size, skeletal age, and motor performance variables contribute to technical actions	3 vs 3 + GK	36 × 27 m	162 m^2 per player	2 × 4 min/ 1 min passive recovery	–	U13 no significant association between maturation with technical actions (NBB) U15 ↑ inverse association between maturation with received balls and neutral balls (NBB)
da Silva et al. [27]	*n* = 16 U15 13.5 ± 0.7 years (Brazilian soccer team)	longitudinal non-bio-banded	to investigate the influence of variations in player numbers on exercise intensity and technical demands; to investigate the relationship between players' maturation status and both exercise intensity and technical performance	3 vs 3 4 vs 4 5 vs 5	30 × 30 m	3 vs 3: 150 m^2 per layer 4 vs 4: 112.5 m^2 per player 5 vs 5: 90 m^2 per player	3 × 4 min/ 3 min active recovery	– no GK – free touches – sudden ball replacement when out of play – scores only valid when all teammates in opponent's half – coach encouragement	no significant correlations between maturation with exercise intensity and technical scores (NBB)

García-Ceberino et al. [24]	*n* = 55 U15/U16 15.54 ± 0.29 years (two Spanish soccer cubs)	cross-sectional non-bio-banded	to investigate how training tasks and maturational age impact external and internal training loads	n. a.	n. a.	n. a.	n. a.	freely designed and organised by the coaches	↑ correlation between maturation with % HIA Rel., % HIA Abs., Acc (2 m/s^2), Dec (–2 m/s^2) (NBB) ↑ inverse correlation between maturation with PL/min (NBB)
Gómez-Álvarez et al. [50]	*n* = 12 11.5 ± 1.33 years (Chilean Recreational soccer school)	cross-sectional non-bio-banded	to explore how physical fitness, anthropometric measures, and biological maturation influence technical performance and perceived enjoyment during continuous- and intermittent-regimen protocols	3 vs 3	17 × 9 m	25.5 m^2 per player	continuous: 1 × 16 min intermittent: 4 × 4 min/ 2 min passive recovery	– no GK – free touches – sudden ball replacement when out of play – scores only valid when all teammates in opponent's half – throw-ins/corner kicks performed by foot – game resumes at half-court after a goal	↑ correlation between maturation with successful shots and efficiency index during intermittent regimen (NBB)
Lüdin et al. [22]	U13 *n* = 32 12.3 ± 0.2 years U14 *n* = 33 13.15 ± 0.25 years (Swiss elite youth soccer club)	cross-sectional bio-banded	to investigate differences in physical and technical-tactical variables when c ompeting in bio-banded versus non-bio-banded formats	9 vs 9 + GK	67 × 56 m	208.4 m^2 per player	2 × 35 min/ 10 min passive recovery	fixed playing positions	↑ conquered balls and attack balls for U14 MO_{low} (BB) ↑ High accelerations for U13 MO_{high} (BB)
Moreira et al. [31]	*n* = 40 15.1 ± 0.2 years (Brazilian major professional soccer club)	cross-sectional non-bio-banded	to investigate the influence of hormonal status, sexual maturity, anthropometric profile, and physical performance on technical abilities	5 vs 5 + GK	60 × 46 m	276 m^2 per player	2 × 8 min/ 3 min passive recovery	–	↑ correlation between maturation with technical performance set (i.e., total number of passes, effectiveness, goal attempts, total tackles) (NBB)
Salter et al. [29]	*n* = 55 U12–U16 13.8 ± 1.4 years (English premier league academy)	cross-sectional bio-banded	to investigate differences in ratings of physiological responses (i.e., RPE) in bio-banded versus non-bio-banded formats	6 vs 6 + GK	45 × 36 m	135.2 m^2 per player	5 × 5 min/ 2 min passive recovery	verbal encouragement	↓ sRPE, RPE-B, RPE-L, and RPE-T for pre-, circa-, and post-PHV (NBB) ↓ RPE-T for post-PHV (NBB)
Towlson et al. [25]	*n* = 92 (72 participating/ 20 reserve players) U13–U16 (three UK-based soccer academies)	cross-sectional bio-banded	to investigate differences in physiological and psychological parameters in bio-banded versus non-bio-banded formats	4 vs 4	23 × 18.3 m	52.6 m^2 per player	5 × 5 min/ 5–15 min active recovery	–	↓ HSRD for post-PHV (BB) ↑ PLAP for circa-PHV compared to pre-PHV (BB) ↑ PL_{ML} for pre-PHV compared to post-PHV (%EPAH) (BB) ↑ PL_{ML} for post-PHV compared to pre-PHV (BB) ↓ HR_{mean} for circa-PHV (BB)

Towlson et al. [47]	*n* = 44 12.9 ± 0.9 years (two UK academies from championship clubs)	cross-sectional bio-banded	to examine the impact of bio-banding on passing networks, considering pitch size and comparing network analysis with coach-based performance assessments	4 vs 4	1) 17 × 17 m 2) 24 × 24 m 3) 29.5 × 29.5 m 4) 34 × 34 m	1) 36.1 m^2 per player 2) 72 m^2 per player 3) 108.8 m^2 per player 4) 144.5 m^2 per player	6 × 5 min/ 3 min passive recovery	– two goals (2 × 1 m) – no GK – shooting zone within the attacking half of the pitch	↑ degree centrality for EMPs (BB) ↑ betweenness centrality for and Page Rank for EMPs (NBB)
Towlson et al. [32]	*n* = 92 (72 participating/ 20 reserve players) U13–U16 (three UK-based soccer academies)	cross-sectional bio-banded	to investigate differences in technical and tactical parameters in bio-banded versus non-bio-banded formats	4 vs 4	23 × 18.3 m	52.6 m^2 per player	5 × 5 min/ 5–10 min active recovery	– two goals (2 × 1 m) – no GK – shooting zone within the attacking half of the pitch	↑ successful passes for pre-PHV and circa-PHV (BB) ↑ turning frequency for circa-PHV (BB) ↑ distance to nearest teammate, opponent centroid, opponent, and centroid for post-PHV (BB) ↑ SEI for circa-PHV (BB)

(A)PHV – (age of) peak height velocity
ACC – accelerations
BA – biological age
BB – bio-banded
DEC – decelerations
EMPs – early-maturing players
GK – goalkeeper
%HIA abs. – absolute high-intensity actions
%HIA rel. – relative high-intensity actions
HR – heart rate
HSRD – high speed running distance
LMPs – late-maturing players
MO – maturity offset
NBB – non-bio-banded
PL/min – player load per minute
PL_{AP} – anterior-posterior player load
PL_{ML} – medial-lateral player load
RPE – rating of perceived exertion
sRPE – session rating of perceived exertion
sRPE-B – rating of perceived exertion for breathlessness
sRPE-L – rating of perceived exertion for leg exertion,
sRPE-T – rating of perceived exertion for technical/cognitive exertion
SEI – spatial exploration index
↓↑ – main effects based on quantifiable outcome measures

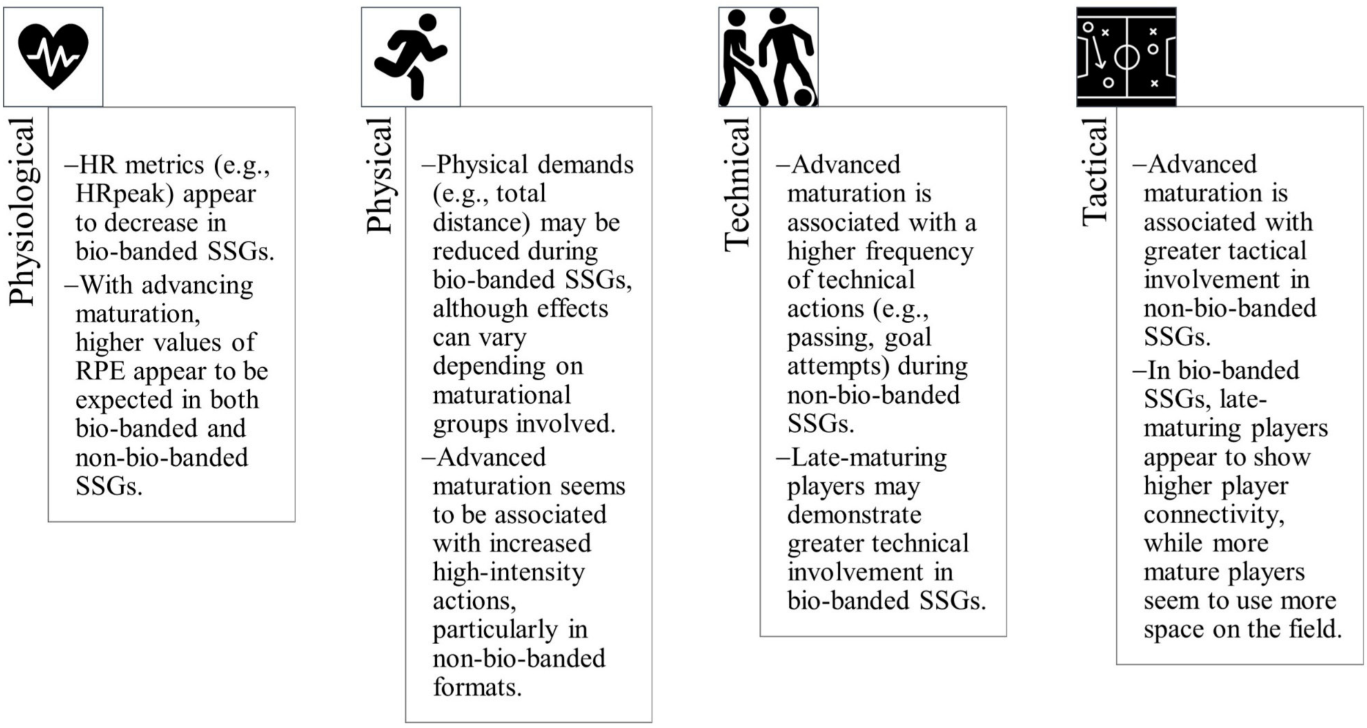


Figure 4. Synthesis of results on maturational influences in physiological, physical, technical, and tactical demands

for both pre- and post-PHV players in non-bio-banded SSGs. Salter et al. [29] observed medium effect sizes (Cohen's d) for session RPE between maturational groups in bio-banded SSGs, with post-PHV players reporting higher values than pre-PHV (*d* = 0.6) and circa-PHV players (*d* = 0.58), as well as for perceived leg exertion (RPE-L) (*d* = 0.56). In non-bio-banded SSGs, post-PHV players exhibited medium effect sizes for breathlessness (RPE-B) (*d* = 0.65), RPE-L (*d* = 0.74), and technical/cognitive demands (RPE-T) (*d* = 0.52) in comparison to circa-PHV players [29].

Arede et al. [26] observed a reduction in HR_{peak} during bio-banded SSGs, while Towlson et al. [25] reported a decrease in HR_{mean} specifically in circa-PHV players. The study by da Silva et al. [27], which measured exercise intensity as a percentage of HR_{max} across 3 vs. 3, 4 vs. 4, and 5 vs. 5 SSG formats, found no significant association between exercise intensity and maturation stage in non-bio-banded SSGs.

Effect of maturation on physical parameters

Three studies investigated the influence of maturation on physical parameters during bio-banded SSGs [22, 25, 26], while one study investigated this on non-bio-banded SSGs [24]. All studies followed a cross-sectional design, with the majority conducted in the UK [22, 25, 26] and one study originating from Spain [24].

Towlson et al. [25] found limited effects on physical parameters in bio-banded SSGs, while Arede et al. [26] observed a reduction in physical metrics (e.g., total distance, decelerations, body impacts) in bio-banded SSGs compared to non-bio-banded formats. However, the use of pooled data across maturational groups in the study precludes the possibility of drawing specific inferences regarding the impact of bio-banding on discrete maturational groups (e.g., early, circa, or late). This, in turn, restricts the scope for insights into intergroup variability.

García-Ceberino et al. [24] identified a positive correlation between the rates of acceleration (2 m/s^2) and deceleration (–2 m/s^2) with both relative and absolute high-intensity actions, indicating that higher maturity levels are associated with an increase in high-intensity actions in non-bio-banded SSGs. Similarly, Lüdin et al. [22] reported a greater number of accelerations (≥ 2.4 m/s^2) among U13 players within more mature bio-bands.

Effect of maturation on technical parameters

Six investigations examined the effects of maturation on technical parameters in both bio-banded [22, 32] and non-bio-banded SSGs [30, 31, 48, 50]. Four studies were conducted in South America, including Chile (*n* = 1) [50] and Brazil (*n* = 3) [30, 31, 48, 49]. Additionally, two studies were from Europe, specifically Switzerland (*n* =1) [22] and the UK (*n* = 1) [32]. All studies employed a cross-sectional design.

Borges et al. [48] identified an association between late-maturing players with degree centrality (i.e., number of passes made by the player within their network) and technical efficiency. Da Costa et al. [30] reported an inverse relationship between skeletal age and neutral passes (i.e., passes to teammates without advancing goal chances or disrupting defence), received passes, and offensive passes.

Technical advantages for early-maturing players are documented in the study by Moreira et al. [31], who found a significant canonical correlation between advanced maturation levels (measured by Tanner stages) and technical performance variables (i.e., number of passes, effectiveness, goal attempts, total tackles). Gómez-Álvarez et al. [50] compared two playing protocols (intermittent vs. continuous) and identified significant positive correlations between advanced age of PHV and both successful shots and technical efficiency index scores, with stronger associations observed during intermittent, non-bio-banded SSGs.

One study reported large effect sizes (Cohen's *d*) between maturational groups in non-bio-banded SSGs, indicating that players with an advanced maturity offset (MO) achieved higher counts of conquered balls (*d* = 1.13; U14 MO_{high} vs U14 MO_{low}), neutral balls (*d* = 0.99; U14 MO_{high} vs U13 MO_{high}), and attack balls (*d* = 0.85; U14 MO_{high} vs U13 MO_{low}) [22]. Interestingly, within the study, the bio-banded format demonstrated significantly elevated counts of attack balls for late-maturing players in the U13 and U14 age groups. Additionally, one study reported higher rates of successful passes among pre-PHV players and increased time spent dribbling the ball by circa-PHV players during bio-banded SSGs [32].

Effect of maturation on tactical parameters

Four cross-sectional studies examined the effect of maturation on tactical parameters, with two studies conducted in Brazil using non-bio-banded SSGs [48, 49] and two studies from the UK employing a bio-banded format [32, 47].

Borges et al. [48, 49] observed significant correlations between closeness centrality (i.e., indicating a player's capacity to reach more players in fewer passes), and degree prestige (i.e., measured by the number of passes received, with high values reflecting frequent receipt of passes) in the U13 age group, but not in the U15 in non-bio-banded SSGs. Towlson et al. [47] observed a reduction in degree centrality and closeness centrality, accompanied by an increase in betweenness centrality, which reflects how often a player positions themselves between teammates. In the same study, the PageRank metric, which estimates the likelihood of a player receiving or passing the ball after several passes within the team, was higher for early-maturing players in non-bio-banded SSGs. Towlson et al. [32] reported that, in bio-banded SSGs, post-PHV players exhibited the greatest distances to their nearest teammate or opponent, as well as to the team's or opponent's central position. Circa-PHV players displayed the highest spatial exploration index, indicating their tendency to utilise more space on the field.

Discussion

Physiological parameters

In terms of physiological parameters, the results of the review suggest that pre-PHV players competing in non-bio-banded SSGs had elevated mean HR and $\%HR_{max}$ values in addition to higher RPE levels. This could be attributed to the relatively lower absolute physical capacities of pre-PHV players, which may require them to exert greater relative effort to keep up with their more mature peers during non-bio-banded SSGs [51]. For these players, the implementation of bio-banded SSGs may facilitate the creation of a more balanced competitive environment and moderate intensity levels. This may result in a reduction of physical strain on less mature players and those around their PHV, while simultaneously maintaining opportunities for high-intensity physical engagement [51–53].

For non-bio-banded SSGs, a limited association between $\%HR_{max}$ and maturation was found [27], suggesting that the SSG format itself may have a more pronounced influence on the internal load than the maturational stage of the players. As emphasised by Clemente et al. [54], the within- and between-session variability in internal load responses during SSGs must be carefully considered. Nevertheless, other studies have underscored the influence of maturation on the development of physiological parameters. Aerobic endurance capacity, including factors such as oxygen uptake kinetics, develops alongside biological maturation due to physiological adaptations. These include increases in the size of the heart, lungs, and muscles, an expansion in blood volume, the activation of cellular aerobic enzymes, and elevated levels of circulating hormones (e.g., testosterone) [55]. This progression aligns with findings from existing studies, which observed significant improvements in aerobic performance with advanced PHV [56, 57]. Therefore, future studies should aim to explore physiological responses in greater depth, examining additional physiological parameters (e.g., lactate concentration levels) and how maturation affects both acute and cumulative internal load responses across various SSG formats.

Physical parameters

It appears that there is a paucity of empirical evidence to elucidate the impact of maturation on physical variables in SSGs. While some scientific research indicates that maturation has no effect on physical variables, high-intensity variables, particularly accelerative (≥ 2 m/s²) and decelerative (–2 m/s²) actions, seem to increase with higher maturity levels in non-bio-banded SSGs. An explanation for the observed elevation may be found in a recent study that provides a detailed analysis of the relationship between myotonometric parameters (e.g., muscle tone, stiffness, elasticity, and relaxation) and dynamic activities such as sprinting, agility, and jumping across various maturational stages in youth soccer players [36]. The findings indicate that early-maturing players exhibit significantly higher values in these biomechanical properties, which may account for their enhanced performance in linear sprinting (e.g., 10 m, 20 m, 30 m, 50 m) and change-of-direction tasks (e.g., *T*-test, 5-0-5 test) [15, 36]. Moreover, morphological adaptations, in conjunction with enhanced neural development (e.g., motor unit recruitment) [58] and executive functions (e.g., inhibition) [59], may facilitate faster responses, stronger physical interactions, and a higher frequency of high-intensity efforts among more mature players – demands that are more likely to be elicited in the smaller, more constrained spaces typical of SSGs [1, 60]. Given that accelerations and decelerations are critical physical determinants of performance in soccer [61], practitioners working with early-maturing players may consider SSGs as a representative approach to enhance these movement patterns.

Technical parameters

A review of the scientific literature reveals a lack of conclusive evidence regarding the influence of maturation on technical abilities in non-bio-banded SSGs. This is consistent with findings by Vandendriessche et al. [34], who observed no association between advanced maturity status and soccer-specific or general motor coordination in U15/U16 international youth soccer players. Similarly, studies on younger age groups (11–15 years) by Figueiredo et al. [62, 63] demonstrated that there was no significant contribution of maturity status to the variance in soccer skill indicators such as ball control, dribbling, wall passes, and shooting across all age groups.

In contrast, bio-banded SSGs have demonstrated an increase in technical actions among both early-maturing players (e.g., successful passes) and late-maturing players (e.g., attack balls). Similar trends were observed in official matches, with early-maturing players executing a higher frequency of short passes, late-maturing players attempting fewer long passes, and a general reduction in ball possession time, which corresponded to faster transitions in match play scenarios [21, 64]. These findings support the objective of bio-banding in levelling the playing field and promoting a higher density of technical actions across maturational groups [65]. By reducing the physical advantages associated with advanced maturity and providing more equitable opportunities for skill expression, bio-banded SSGs may provide a more inclusive developmental framework, encouraging balanced technical skill acquisition across maturational groups.

The influence of maturation on technical dynamics in non-bio-banded SSGs indicates the existence of potential trends that warrant further investigation. Early-maturing players may adopt adaptive strategies, such as greater dispersion, higher connection rates with teammates, and more frequent physically demanding technical actions (e.g., tackles, goal attempts), distinguishing them from their less mature peers [22, 31]. Conversely, less mature players may prioritise lower-intensity technical actions, emphasising precision, spatial awareness, and timing during non-bio-banded SSGs [30, 49]. While existing research points to maturational selection biases, particularly in offensive roles [66], these patterns should be further explored to understand their implications for player development and positional assignments.

Tactical parameters

Regarding centrality measures during non-bio-banded SSGs, early-maturing players contribute more significantly to their team's offensive network [47, 49], while late-maturing players often assume more peripheral tactical roles. For instance, for early-maturing players, high closeness centrality values might allow them to connect with teammates in fewer passes, making them pivotal for quick ball circulation and transitions. Furthermore, their high degree centrality shows they actively engage with more teammates, contributing significantly to team structure, while their high degree prestige indicates they are preferred passing targets, trusted for advancing play [49, 67].

The implementation of bio-banding has been shown to foster a more balanced competition format, eliciting tactical adaptations particularly among early-maturing players (e.g., quicker decision-making) and late-maturing players (e.g., creative problem-solving) [53, 65]. In this context, on an inter-team level, the implementation of bio-banding (post-PHV vs post-PHV) in the study by Towlson et al. [32] may explain the increased distances to team and opponent centroids, as both teams seek to benefit from spatial separation (e.g., minimising defensive pressure). This spacing strategy aligns with the findings by Clemente et al. [5], who found that players in older age groups are more adept at implementing strategies that require spatial exploration and positional adjustments. However, while the tactical behaviours of post-PHV players in the study by Towlson et al. [32] align with patterns observed in older, typically more mature players, direct comparisons should be approached cautiously, as variations in maturity, playing experience, and SSG formats may influence these dynamics.

Although tactical adjustments in bio-banded SSGs have been observed for post-PHV players, Towlson et al. [32] emphasise the need for further research to draw definitive conclusions about the effects of bio-banded SSGs on tactical parameters. Pitch dimensions, in particular, deserve special attention, as smaller pitches tend to amplify tactical behaviours and dynamic player interactions in bio-banded settings [47]. Conversely, larger pitch sizes may serve as a tactical stimulus for more advanced maturing players to capitalise on their physical advantages, offering new insights into tailored SSG designs.

Limitations

This review has limitations that must be acknowledged. First, discrepancies in the reported effects of maturation on performance outcomes may be attributed to variations in the methods employed to assess maturity status across studies. Due to the moderate to poor concordance within and between invasive and non-invasive methods to assess maturity status [68], the classification of players as 'early-', 'on-time-', or 'late-maturing' in the included studies should be interpreted with caution. Furthermore, it is essential to acknowledge the inherent limitations of each methodology used to assess maturity status, including generalisation bias, estimation errors, and validity concerns [68–70]. The influence of contextual factors beyond maturation on SSG dynamics was outside the primary scope of this review and thus not extensively examined. This limitation may obscure potential moderating effects of SSG modalities (e.g., player numbers, pitch size) on maturational influences. Furthermore, the role of maturation on psychological measures (e.g., self-confidence, motivation) in SSGs remains under-investigated, thus omitting an important dimension of youth soccer player development [13]. The predominance of research conducted in Europe and South America, primarily using male samples with varying expertise levels, limits the generalisability of findings across different regions, genders, and skill levels. This geographic and demographic bias restricts the understanding of maturational influences on SSG in diverse contexts and a broader applicability of the results. Lastly, methodological limitations, including insufficient reporting on sample size determination and inherent weaknesses of cross-sectional designs (e.g., limited external validity, susceptibility to selection bias), should be acknowledged [71, 72].

Future directions

Our findings could inform future study designs, facilitating systematic reviews or meta-analyses that address specific research questions and strengthen the evidence base. For instance, given the potential influence of contextual constraints on performance in SSGs, future research should investigate the interaction between maturation and task constraints (e.g., goal configurations, numerical imbalance) to better understand their combined effects. Further exploration of how different SSG task constraints impact specific maturational stages would provide valuable insights for optimising training programs, particularly for age groups most affected by maturational differences.

Future studies should expand on existing research, particularly by examining different playing levels, genders, and countries. Notably, to the authors' knowledge, no study has investigated the interaction between maturation and performance outcomes in SSGs within female cohorts across any sport. Additionally, the interaction between psychological skills and maturation requires further investigation [73]. Such research could help establish individualised approaches to address maturational challenges in SSG interventions for youth soccer players. Most studies included in this scoping review employed a cross-sectional design, revealing a critical gap in the literature regarding the training effects of SSG interventions across specific maturational groups. As a consequence, longitudinal studies are needed to provide insights into the developmental trainability of adolescent soccer players and a more comprehensive understanding of the long-term impact of SSGs on physiological, physical, technical, and tactical parameters [45].

Practical implications

The findings of this review have implications for practitioners in youth soccer. First, maturational effects occur during SSGs under various conditions. Given that SSGs are a commonly used training method, coaches should be aware of their moderating impact on performance in youth soccer players.

Late-maturing players may experience greater physiological strain in non-bio-banded SSGs, potentially increasing injury risk. The present findings suggest that bio-banding can help regulate physical demands and mitigate internal load for vulnerable player groups. If bio-banding is not feasible, alternative strategies in non-bio-banded SSGs – such as incorporating goalkeepers, emphasising possession play, creating overload situations, increasing player numbers and pitch size, or adjusting work-to-rest ratios – offer practical solutions for reducing physical demands in SSGs [74]. On the other hand, the load-tolerant player can be challenged by participating in higher-load conditions (e.g., numerical inferior teams).

In talent identification, scouts and coaches should consider maturity effects in non-bio-banded SSGs, where early-maturing players may temporarily excel in technical (e.g., number of passes) and tactical (e.g., positioning) skills. Bio-banded SSGs can provide late- and on-time-maturing players with greater opportunities to develop these skills, potentially enhancing long-term player development. Finally, existing evidence on SSG characteristics should be considered when planning training sessions. Intermittent SSG protocols may enhance technical efficiency in non-bio-banded formats, potentially making them more beneficial for skill acquisition in adolescent players [50]. On the other hand, small relative areas per player (< 52 m^2) may limit bio-banding's effectiveness on technical executions [47].

Conclusions

This review is the first to scope the scientific literature on performance dimensions influenced by maturation in SSGs. The results from 14 included studies indicate that physiological, physical, technical, and tactical outcomes are sensitive to maturation. The increasing number of publications since 2011 underscores the growing scientific interest in this area. Research has focused equally on bio-banded and non-bio-banded SSGs, with technical parameters being the most frequently analysed. Geographically, studies are predominantly conducted in South America and Europe, primarily involving highly trained youth soccer players (U12–U16) from elite academy settings. Further research should concentrate on replicating and extending these findings in order to enhance the comprehension of the relationship between maturation and performance in both bio-banded and non-bio-banded SSG formats.

Data availability statement

All data supporting the findings of this study are available in the Open Science Framework repository.

Ethical approval

The conducted research is not related to either human or animal use.

Informed consent

Informed consent was obtained from all individuals included in this study.

Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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