Rev Bras Cineantropom Desempenho Hum

review article

https://doi.org/10.1590/1980-0037.2025v27e95895

Comparison of physical responses in bio-banding games and chronological age football games: a systematic review

Comparação das respostas físicas em jogos de futebol por bio-banding *e por idade cronológica: uma revisão sistemática*

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Abstract – The aim of this systematic review was to identify and synthesize the available information in studies that compare the physical responses of young football players subjected to games in two distinct competition models: the bio-banded model, which considers the stage of biological maturation, and the chronological model, based solely on the age of the players. The conduction of this review followed the guidelines of the Preferred Reporting Items for Systematic and Meta-Analyses (PRISMA). Bibliographic searches were performed in three databases: PubMed, Web of Science, and SCOPUS, using the following descriptors: "soccer game", "physical performance", "biological maturation", and "bio-banding". The inclusion criteria were articles with experimental studies conducted in a game context, which compared the physical responses of players during bio-banded and chronological competitions, with the aim of investigating the influence of biological maturation on these responses. The initial search resulted in 336 records, of which 4 articles comprised the final sample. The methodological quality of the included studies was assessed as medium to high. The findings suggest that biological maturation has an influence on the physical responses of young football players, and that both late-maturing and early-maturing players can benefit from games organized by biological maturation status.

Keywords: Growth; Physical performance; Soccer.

Resumo – *O objetivo desta revisão sistemática foi identificar e sintetizar as informações disponíveis em estudos que comparam as respostas físicas de jovens jogadores de futebol submetidos a jogos em dois modelos distintos de competição: o modelo por bio-banding, que considera o estágio de maturação biológica, e o modelo cronológico, baseado unicamente na idade dos jogadores. A condução desta revisão seguiu as diretrizes do Preferred Reporting Items for Systematic and Meta-Analyses (PRISMA). Realizaram-se buscas bibliográficas em três bases de dados: PubMed, Web of Science e SCOPUS, utilizando os seguintes descritores: "jogo de futebol", "desempenho físico", "maturação biológica" e "bio-banding". Os critérios de inclusão foram artigos com estudos experimentais conduzidos em contexto de jogo, que comparassem as respostas físicas de jogadores durante competições organizadas por bio-banding e cronológicas, com o intuito de investigar a influência da maturação biológica nessas respostas. A busca inicial resultou em 336 registros, dos quais 4 artigos compuseram a amostra final. A qualidade metodológica dos estudos incluídos foi avaliada como média a alta. Os achados sugerem que a maturação biológica tem influência nas respostas físicas de jovens jogadores de futebol, e que, tanto os jogadores com maturação tardia, como os com maturação precoce, podem se beneficiar dos jogos organizados por status de maturação biológica.*

Palavras-chave: *Crescimento; Desempenho físico; Futebol.*

Received: April 08, 2025
Accepted: September 04, 2025

How to cite this article
Moré RAS, Dellagrana RA. Comparison of physical responses in bio-banding games and chronological age football games: a systematic review. Rev Bras Cineantropom Desempenho Hum 2025, 27:e95895. DOI: http://doi.org/10.1590/1980-0037.2025v27e95895

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Scientific Editor
Diego Augusto Santos Silva

INTRODUCTION

Football is one of the most popular sports worldwide[1], practiced by individuals of all ages, with significant participation among children and adolescents. For training and competition, young players are typically grouped into chronological age categories, usually spanning up to two years, based on a predetermined cutoff date (January 1st is globally recognized as the beginning of the selection year)[2]. Brazilian football is organized into the following categories: Under-11 (10 to 11 years old), Under-13 (12 to 13 years old), Under-15 (14 to 15 years old), Under-17 (16 to 17 years old), and Under-20 (18 to 20 years old)[3]. As a result, within the same category, players may differ by as much as 24 months in chronological age, which can result in disparities in physical performance[4], as chronologically older players tend to be more advanced in their physical and cognitive development compared to their relatively younger peers[5].

Altimari et al.[6] demonstrated that stature, body mass, lean body mass, and repeated sprint ability in the Under-13 and Under-15 categories were influenced by birth date, favoring chronologically older individuals. Abarghoueinejad et al.[7] and Vaeyens et al.[8] reported that physical characteristics, performance, and skill of football players differ between age groups, again favoring older players. Consequently, there is a strong tendency for these individuals to have a greater chance of being selected by elite teams, especially in youth categories[9].

Within the same age category, differences among players may arise due to their maturational status, which does not necessarily correspond to chronological age[10]. Biological maturation refers to the process of progression towards a mature adult state and can be assessed in terms of status, defined as the level of maturation an individual has reached at the time of observation[11].

Since biological maturation affects body size, strength, power, and physical performance, players with advanced maturation tend to dominate the game because they have a performance advantage within their age category[12,13]. A study by Yang and Chen[14] confirmed that the anthropometric characteristics (height and body mass) and physical attributes (5 × 25 m repeated sprints, long jump, and agility test) of 13- to 15-year-old players with advanced maturation were significantly superior to those of their late-maturing counterparts.

As an attempt to reduce these physical variations associated with maturation in team sports, a system called bio-banding has recently been created. In this model, players are grouped by their maturational status instead of by their chronological age. For example, young athletes between 11 and 15 years old are organized into "bands" based on their maturational stage[12]. The objectives of bio-banding are to reduce the variation in physical attributes (anthropometry and physical fitness) between teams, promote competitive equivalence, prevent injuries, and facilitate talent identification and development[12]. This approach appears to create homogeneous groups of players characterized by similar anthropometric and physical qualities[15]. Consequently, this type of competition allows individuals to develop optimally while being exposed to new experiences and challenges[12,16,17].

In this context, several studies have been conducted comparing the performance and perceptual responses of young players when participating in teams organized by bio-banding versus chronological age[13,16-20]. These studies have found that, during games or competitions organized by bio-banding, competing against peers at the same maturational stage, and with greater physical ability led advanced-maturing players to realize they could no longer rely on their physical advantages.

Thus, this encouraged them to use and develop their technical and tactical attributes. Conversely, for late-maturing players, the more physically balanced competitive environment provided a greater opportunity to use and demonstrate their physical and technical attributes[20]. Bradley et al.[19] observed that advanced-maturing players reported bio-banded games were physically more challenging, while late-maturing players perceived these games as physically less challenging.

In addition to players' perceptions, comparing the physical demands between bio-banded games and games grouped by chronological age may be important for understanding the advantages and disadvantages of implementing bio-banded in training or even in official competitions. Despite the growing number of studies in this area, to our knowledge, no systematic review has yet focused on comparing competitions organized by biological bands and chronological age. Thus, the aim of this study was to identify the scientific evidence available in studies and to summarize the existing information regarding the comparison of bio-banded and chronologically-grouped games on physical responses during football matches.

METHODS

Protocol

A systematic review of the existing scientific literature was conducted, based on the guidelines recommended by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)[21]. The review protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO registration number: CRD42021278390).

Sources of information and search strategy

A first search was conducted in July 2023 across the PUBMED, SCOPUS, and Web of Science databases. A second search was performed in May 2025 to check for new articles on the same topic that could be added to the present review. The search terms were divided into three categories: 1) Soccer game: "soccer match" OR "soccer game" OR "football match" OR "football game" 2) Physical performance: "physical performance" 3) Biological maturation: "biological maturation" OR "bio-banding". Subsequently, the reference lists of the selected articles were screened to check for potential articles to be included in the review.

Eligibility criteria

The inclusion criteria were defined according to the PICOT approach (Population, Intervention/Exposure, Comparator, Outcome, Study Type)[22]. The population consisted of youth football players; the intervention/exposure was physical performance/physical responses; the comparator was maturational stage and chronological age; the outcome was differences in physical performance according to maturational stage and chronological age; and the study type was experimental studies conducted in the context of football games, comparing the physical responses of players during competitions organized by bio-banding and chronological age. The inclusion of studies was decided by consensus between the first and second authors.

Methodological quality assessment

To evaluate and classify the methodological quality of the studies, we used a scale adapted from Sarmento et al.[23], which was previously employed in their systematic review. For its application in our research, an adaptation of item Q4 of the scale was necessary. This scale allows for the evaluation of articles based on the following criteria: objective (Q1), participant characteristics (Q2), sample justification (Q3), bio-banding procedures (Q4), statistical procedures used (Q5), results (Q6), study method conclusion (Q7), practical implications (Q8), limitations (Q9), and future direction (Q10). Each of the ten quality criteria is scored on three levels: zero (no), one (maybe), and two (yes), for a maximum of 2 points per item. Total scores range from zero to twenty, with the sum of the scores from all questions being computed. The total score is then converted into percentages (ranging from 0 to 100%) to ensure an equitable quality assessment among all included articles. The studies were categorized into three levels of methodological quality: high (≥75%), moderate (50-74%), and low (<50%).

Study selection

The two researchers conducted the online search independently. To be included in this review, studies had to meet the following inclusion criteria: studies conducted in the context of a football game; only studies with quantitative data that compared bio-banded and chronologically-grouped competitions to evaluate and compare the physical responses of young football players; original articles published in peer-reviewed journals; full text available in English; and the sample and applied methods were reported in the article (e.g., data collection, study design, instruments, and results).

Based on the eligibility criteria, articles were initially selected using their title and abstract, and those selected had their full text analyzed. Eligible articles had to be selected by both researchers, and if any discrepancies were observed at this stage, the researchers would discuss and resolve the inclusion. After the selection of the manuscripts to be included, one of the researchers examined the reference lists of the selected articles to identify other potentially relevant articles for the review.

Data extraction

The following data were extracted from each selected study: authors, year of publication, participants, age, sample size, study objective, type of maturational stage assessment, and the physical responses of players from each maturational stage in both types of competition (bio-banding and chronological). This included total distance covered, distances covered at different speeds, accelerations, and rating of perceived exertion (RPE).

RESULTS

Study selection

The systematic search identified 336 studies from the three investigated databases (PubMed: 79; SCOPUS: 174; and Web of Science: 83).

After removing 69 duplicates, 267 studies were submitted for analysis according to the eligibility criteria. In the subsequent step, 232 studies were excluded based on title screening. Reading the abstracts of the remaining 35 studies led to the removal of another 21 for not meeting the predefined eligibility criteria. The 14 remaining articles were then selected for full-text evaluation. Finally, 10 studies were removed, resulting in 4 articles that met all inclusion criteria and were, therefore, included in this review at the end of the screening process. A detailed representation of the screening procedures is presented in the PRISMA flow diagram (Figure 1).

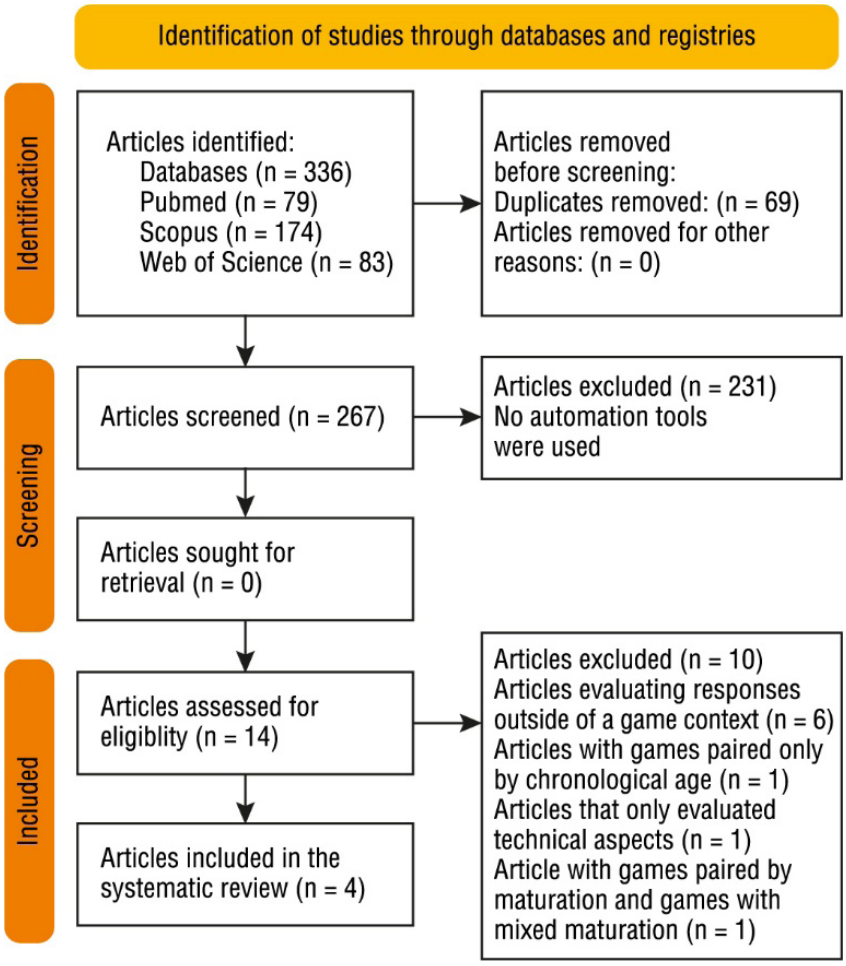

Figure 1. Flowchart including literature search and selection steps following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Assessment of study quality

The average quality score of the articles was 82.5% ± 8.6%, as can be seen in Table 1. In order from the lowest to the highest quality score: Romman et al.[16] = 70% (moderate quality); Lüdin et al.[13] = 85% (high quality), Arede et al.[24] = 85% (high quality). Abbott et al.[18] = 90% (high quality). The total score tended to be moderate-to-high, indicating that the average quality level of the included studies was very satisfactory. The noted deficiencies were mainly related to question 3 (justification for the study's sample size).

Table 1. Methodological quality assessment of the articles.

		Abbott et al. (2019)	Arede et al. (2024)	Lüdin et al. (2022	Romman et al. (2020)
Q1	Was/were the study objective(s) clearly defined?	2	2	2	2
Q2	Were the participant characteristics presented in detail in the methods section? (number of subjects, sex, age, country/city)	2	1	1	2
Q3	Was the sample size justified?	0	0	0	0
Q4	Is the bio-banding procedure clearly described in the methods section?	2	2	2	2
Q5	Were the statistics presented clearly?	2	2	2	2
Q6	Result details (means and standard deviations and/or change/difference, effect size/mechanistic magnitude-based inference).	2	2	2	1
Q7	Were the conclusions adequate considering the study methods and objectives?	2	2	2	1
Q8	Are there practical implications given the study's results?	2	2	2	1
Q9	Were the study's limitations recognized and described by the authors?	2	2	2	1
Q10	Is there any future direction described by the authors?	2	2	2	2

Study locations

The four studies were conducted in Europe: one study in England[18], one in Portugal[24], two in Switzerland[13,16].

Sample size and study design

Physical responses were investigated in a total of 268 young football players, representing an average of approximately 67 players per study. The four studies used a cross-sectional design, with sample sizes ranging from 25[18] to 116[24] participants and with ages varying between 11 and 15 years. In the Abbott et al.[18] study, players participated in two 11 vs 11 matches with four 20-minute periods on a standard pitch (100 x 64 m), with one match in a bio-banding format and the other in a chronological age competition format. In the Lüdin et al.[13] study, players also participated in one match in a bio-banding format and the other by chrqonological age; however, the games were 9 vs 9, with two 35-minute halves and a 10-minute interval between them, and the pitch size was 56 x 67m. In the Arede et al.[24] study, the players completed eight games, with four matches organized by bio-banding and four matches by chronological age, each lasting 20 minutes, with 7 players per team on a 64 x 45m pitch. In the Romman et al.[16] study, players participated in 8 matches, with half of them in a bio-banding grouping format and the other half by chronological age. The matches had a duration of 20 minutes each, and the pitch size was 55 x 58 m.

Assessment of maturational status

The four studies assessed the biological maturation of the participants. Two studies, Abbott et al.[18] and Arede et al.[24], used the Khamis-Roche equation[25] to calculate the percentage of participants' predicted adult height, then divided the participants into three maturational groups: early, average, and late. The studies by Lüdin et al.[13] and Romman et al.[16] used the maturity offset proposed by Mirwald et al.[26] to assess somatic maturation. In both studies, to perform the bio-banding procedure, participants were divided into two bands based on the median maturity offset of the participants.

Tools for physical data assessment

The physical performance data from the three studies were collected using a global positioning system (GPS) and accelerometer devices. In the study by Abbott et al.[18], the GPS units were 10Hz and the accelerometers were 100Hz (OptiumEye S5B, version 7.18; Catapult Innovations, Melbourne, Australia). In the study by Arede et al.[24], two GPS models were used: 8 units of 10Hz (STATSports, Apex, Northern Ireland) and 12 units of 15Hz (SPI-Pro X II, GPSports, Canberra, Australia). In the Lüdin et al.[13] study, a local positioning measurement (LPM) system was used (inmotiotec GmBH, 2010, Regau, Austria) at 24 Hz. In the Romman et al.[16] study, the physical parameters were measured using a global positioning system (FieldWiz, Sensitch AG, Goldach, Switzerland) at 18Hz.

Synthesis of results

The results were synthesized in Table 2. Overall, the reviewed studies sought to determine differences in physical performance by conducting one competition organized by bio-banding and another by chronological age. Physical and physiological performance was determined from data on: total distance covered; high-speed running distances ([>5.5 $m \cdot s^{-1}$][13] and [≥15.8 $km \cdot h^{-1}$][16,18]); accelerations ([>2$m \cdot s^{2}$][18],[>2.4$m \cdot s^{2}$][13],and [>3$m \cdot s^{2}$][24]); decelerations ([<3$m \cdot s^{2}$][24]); distances covered at different intensities[16]: walking (0–5.8 $km \cdot h^{-1}$), jogging (5.8–11.5 $km \cdot h^{-1}$), running (11.5–15.8 $km \cdot h^{-1}$), high-speed running (15.8–20.0 $km \cdot h^{-1}$) e sprint (>20.0 $km \cdot h^{-1}$)[16], mean velocity[24], peak velocity [24] and rating of perceived exertion (RPE)[18].

Regarding total distance covered and high-speed running distance, no significant differences were found between the competition formats in the different maturational groups in the studies by Abbott et al.[18] and Lüdin et al.[13]. It is worth noting that in the study by Abbott et al.[18], it was evident that late-maturing players produced significantly greater total distances compared to advanced-maturing players in both grouping formats (bio-banding and chronological age).

In contrast, in the study by Romman et al.[16], bio-banding reduced the total distance covered during jogging (5.8 to 11.5 $km \cdot h^{-1}$), running (11.5 to 15.8$km \cdot h^{-1}$),and high–speed running (15.8 to 20.0$km \cdot h^{-1}$) when compared to chronological age games. The reduction in distance covered during bio-banded matches was also observed in the study by Arede et al.[24]

Regarding accelerations, significant differences were observed between the competition formats. This indicated a greater number of accelerations during bio-banded games compared to chronological age games for advanced-maturing players in the U-13 category (ES=0.6)[13]. In the same study, late-maturing (ES=0.6) and advanced-maturing (ES=0.5) players in the U-14 category had a greater number of accelerations in the chronological competition when compared to the bio-banded competition.

In the study by Arede et al.[24], the number of accelerations and decelerations was lower in games organized according to biological maturation. In the study by Abbott et al.[18], although no significant differences were found between the competition formats, it was demonstrated that late-maturing players produced a greater number of accelerations compared to those maturing during the PHV and advanced-maturing players (post-PHV). In the study by Romman et al.[16], the number of high accelerations was similar in both types of competition.

The distances covered at different intensities were similar between the competition formats for walking and sprinting. However, the distances covered during jogging and running were reduced with bio-banding in the study by Romman et al.[16]. In the study by Abbott et al.[18], advanced-maturing players presented higher RPE scores in bio-banded games compared to chronologically-grouped games. It was also evident that late-maturing players showed higher RPE scores when compared to advanced-maturing players[18].

Table 2. Characteristics of the studies included in the review.

Author/ Country	Study Design	Age (years)	n	Physical responses assessed	Main results	Quality Index
Abbott et al.[18] / England	Randomized crossover study.	12.7±1.0	25	Total distance (m); Distance covered at high speed >5.5 m·s-1 (m); Accelerations >2 m·s2 ou Deceleration <2 m·s2; e RPE	Players with advanced maturation produced higher rates of perceived exertion in bio-banding games compared to chronological age games. RPE Chronological 6.6±0.5 RPE Bio-banding 7.5±0.9	90%
Arede et al.[24] / Portugal	Randomized crossover study.	13.3±0.9	116	Total distance covered (m); Accelerations >3 m·s2 or Decelerations <3 m·s2; Average speed (km·h–1) and peak speed (km·h–1).	The total distance was shorter in the bio-banding competition (69.26±19.03) compared to the chronological competition (84.70±13.11) (ES= 1.1); the number of decelerations was lower in the bio-banding competition (4.08±1.74) compared to the chronological competition. o (5.03±1.73) (ES= 0.82); the average speed was lower in the bio-banding competition (3.98±1.10) compared to the chronological competition. (4.88±0.76) (ES= 1.15)	85%

*Mean age calculated from the four groups presented in the study. ** mean age calculated from the two groups presented in the study.

Table 2. Continued...

Author/ Country	Study Design	Age (years)	n	Physical responses assessed	Main results	Quality Index
Lüdin et al.[13] / Switzerland	Randomized crossover study.	12.7±0.4*	65	Total distance (m); Distance covered at high speed >15.8km·h-1 (m); Number of accelerations >2.4 m·s2	Advanced maturation players (under-13) had a higher number of accelerations in bio-banding competition (64±25) compared to chronological competition (47±13) (ES= -0.6). The late-maturing players (U-14) had a greater number of accelerations in the chronological competition (57±17) in comparison to the competition *bio-banding*(48±13) (ES=0.6); The advanced-maturing players (U-14) had a greater number of accelerations in the chronological competition(75±24) in comparison to the competition *bio-banding* (62±19) (ES=0.5)	85%
Romman et al.[16] / Switzerland	Paired crossover study.	12.7±0.4**	62	Distances covered classified by velocity: Walking = 0–5.8 km·h-1; Jogging= 5.8–11.5 km·h-1; Running = 11.5–15.8 km·h-1; High-speed running=15.8–20.0 km·h-1; Sprint = >20.0 km·h-1	Bio-banding reduced the total distance covered (1.83±0.40 vs. 1.94±0.39 km) and the jogging distances covered (0.69±0.24 vs. 0.75±0.25km),running (0.30±0.13 vs. 0.32±0.14km) and high-speed running distances (0.11±0.06 vs. 0.12±0.07 km) in comparison to the chronological competition.	70%

*Mean age calculated from the four groups presented in the study. ** mean age calculated from the two groups presented in the study.

DISCUSSION

This review aimed to examine the effects of biological maturation on the physical responses of young football players. Although the number of studies remains limited, a preliminary analysis of the available evidence revealed considerable similarity in study protocols and designs. All studies included in this review compared the effects of biological maturation during football matches (formal games or small-sided games) organized by bio-banding and by chronological age. The available evidence indicates that late-maturing players generally experience greater physical demands, covering longer total distances, performing a higher number of high-intensity accelerations, and reporting higher ratings of perceived exertion (RPE)[18]. Therefore, the higher RPE observed in late-maturing players in the study by Abbott et al.[18] is likely the result of a habitual effort to compete with and against athletes of greater physical development during the usual chronological competition.

As late-maturing players generally have lower physical fitness, match-induced fatigue symptoms may be more prevalent in these players[27].

However, when comparing bio-banded and chronological-age competitions, two of the studies reported no significant differences in physical demands[13,18]. In contrast, the other two studies found a reduction in total distances[16,24], in the distances covered at different intensities (total distance, jogging, running, and high-speed running)[16], in the number of decelerations[24] and in the lowest mean velocity[24] in the bio-banding competition. These findings complement those of Cumming et al.[20], who reported that late-maturing players perceived bio-banded competitions as less physically demanding compared to chronological-age competitions. This reduction in physical demand may, in turn, allow the game to emphasize technical and tactical skills[18-20]. Therefore, a more physically balanced environment can provide a greater opportunity for the late-maturing player to demonstrate their technical attributes[20]. This competition format also promotes greater possibilities for them to adopt leadership positions and have more opportunities to dominate the game[19]. In this competition format, coaches and scouts can evaluate late-maturing players in an alternative environment, judging them based on their current level of physical development and biological maturation status[19].

Players with advanced maturation also showed significant differences in physical responses, with a higher number of high-intensity accelerations[13] and greater RPE[18] during bio-banding games compared to chronological age games. This likely happens because the players have to work harder to keep up with opponents who are physically similar[18]. As mentioned earlier, Cumming et al.[20] demonstrated a similar result, as advanced maturation players reported that bio-banding competition increases the physical challenge and produces a superior learning stimulus compared to chronological age competition. Advanced maturation players may not experience this challenge in chronological competition, due to their physical advantages and better physical conditioning compared to their late-maturation peers[19]. So, when competing against players with the same maturation status, they are no longer able to use their physical advantages and need to rely on their technical and tactical skills to succeed[19,20]. Therefore, the environmental diversification provided by bio-banding competition can benefit players with advanced maturation, preparing them for future challenges where they will face athletes of similar or even more advanced maturation (i.e., in open and adult competitions)[20].

However, although the initial evidence is promising, the current review showed that few studies evaluate the physical and physiological demands during football games, comparing competitions or games grouped by bio-banding and chronological age. Therefore, more research is needed to better understand and validate the potential benefits and limitations of bio-banding competition in relation to the physical performance of players.

This study has some limitations that deserve consideration. First, the research was restricted to three databases, which implies that journals indexed on other platforms may not have been included in this review. Second, the search used only English descriptors, which possibly excluded relevant articles published in other languages. Additionally, we recognize that the limited number of studies included in this review prevents a statistically significant comparison of the effect of biological maturation on the physical responses of young players. In most of the selected studies, the players participated in only one bio-banding match and one chronological age match. Finally, a study design was not made that would allow verifying the reproducibility of the presented data and a more in-depth investigation into the impact of the different competition formats.

CONCLUSION

The objective of this systematic review was to provide an overview of the existing evidence on the physical responses of football players in competitions or games organized by bio-banding, compared with those grouped by chronological age. Overall, the findings suggest that bio-banded competition or games may modify physical responses compared to competitions or games organized by chronological age. Specifically, in bio-banded games, the RPE and the number of accelerations tend to be higher compared to games organized by chronological age. In contrast, the total distance covered, as well as distances in low, medium, and high-intensity running, tend to be reduced bio-banding games. Coaches and young football players can use bio-banded competition to more accurately assess athletes, considering their current maturational stage. However, we emphasize the need for further studies investigating the effects of bio-banded competitions, compared with those organized by chronological age, on the physical responses of young players, as only four studies were included in this review.

COMPLIANCE WITH ETHICAL STANDARDS

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. This study was funded by the authors.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Ethical approval

This research is in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: RASM, RAD; Performed the experiments: RASM; RAD; Analyzed the data: RASM, RAD; Contributed reagents/materials/analysis tools: RASM, RAD; Wrote the paper: RASM, RAD.

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