

Integrating physical and tactical factors in football using positional data: a systematic review

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Background: Positional data have been used to capture physical and tactical factors in football, however current research is now looking to apply spatiotemporal parameters from an integrative perspective. Thus, the aim of this article was to systematically review the published articles that integrate physical and tactical variables in football using positional data. **Methods and Materials:** Following the Preferred Reporting Item for Systematic Reviews and Meta-analyses (PRISMA), a systematic search of relevant English-language articles was performed from earliest record to August 2021. The methodological quality of the studies was evaluated using the modified Downs and Black Quality Index (observational and cross-sectional studies) and the Physiotherapy Evidence Database (PEDro) scale (intervention studies). **Results** The literature search returned 982 articles (WoS = 495; PubMed = 232 and SportDiscus = 255). After screening, 26 full-text articles met the inclusion criteria and data extraction was conducted. All studies considered the integration of physical and tactical variables in football using positional data ($n = 26$). Other dimensions were also reported, such as psychophysiological and technical factors, however the results of these approaches were not the focus of the analysis ($n = 5$). Quasi-experimental approaches considered training sets ($n = 20$) and match contexts ($n = 6$). One study analysed both training and play insights. Small sided-games (SSG) were the most common training task formats in the reviewed studies, with only three articles addressing medium-sided (MSG) ($n = 1$) and large-sided games (LSG) ($n = 2$), respectively. **Conclusions:** Among the current systematic review, the physical data can be integrated by player's movement speed. Positional datasets can be computed by spatial movement,

complex indexes, playing areas, intra-team and inter-team dyads. Futures researches should consider applying positional data in women's football environments and explore the representativeness of the MSG and LSG.

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36

Abstract

Background: Positional data have been used to capture physical and tactical factors in football, however current research is now looking to apply spatiotemporal parameters from an integrative perspective. Thus, the aim of this article was to systematically review the published articles that integrate physical and tactical variables in football using positional data.

Methods and Materials: Following the Preferred Reporting Item for Systematic Reviews and Meta-analyses (PRISMA), a systematic search of relevant English-language articles was performed from earliest record to August 2021. The methodological quality of the studies was evaluated using the modified Downs and Black Quality Index (observational and cross-sectional studies) and the Physiotherapy Evidence Database (PEDro) scale (intervention studies).

Results The literature search returned 982 articles (WoS = 495; PubMed = 232 and SportDiscus = 255). After screening, 26 full-text articles met the inclusion criteria and data extraction was conducted. All studies considered the integration of physical and tactical variables in football using positional data ($n = 26$). Other dimensions were also reported, such as psychophysiological and technical factors, however the results of these approaches were not the focus of the analysis ($n = 5$). Quasi-experimental approaches considered training sets ($n = 20$) and match contexts ($n = 6$). One study analysed both training and play insights. Small sided-games (SSG) were the most common training task formats in the reviewed studies, with only three articles addressing medium-sided (MSG) ($n = 1$) and large-sided games (LSG) ($n = 2$), respectively.

Conclusions: Among the current systematic review, the physical data can be integrated by player's movement speed. Positional datasets can be computed by spatial movement, complex indexes, playing areas, intra-team and inter-team dyads. Futures researches should consider applying

59 positional data in women's football environments and explore the representativeness of the MSG
60 and LSG.

61 **Keywords:** tracking systems, movement, complexity, training, match

1. Introduction

Football can be characterized as a complex and dynamical system where the players collect ecological information's to make decisions, allowing them to gather numerical and spatial advantageous with a goal-orientation through the phases of play (Duarte et al., 2012; Folgado et al., 2014; Hewitt et al., 2016). Hence, football players carried out intermittent movements to perform individual and collective tactical actions (Clemente et al., 2020; Duarte et al., 2012; Low et al., 2019). The tracking systems have been used to compute spatiotemporal measures and assess players' position during training and match activities (Lames et al., 2010; Marcelino et al., 2020; Pol et al., 2020). Positional data can be captured at different frequencies by tracking systems such as global navigation satellite systems (GNSS) or global positioning systems (GPS) (Beato et al., 2018; Rago et al., 2019; Teixeira et al., 2021), local radio-based local positioning (LPM) (Hoppe et al., 2018; Leser et al., 2011; Ogris et al., 2012) and computerized-video or optical-based tracking systems (Beato & Jamil, 2018; Castellano et al., 2014; Di Salvo & Marco, 2006). The players and ball positioning can be computed by Cartesian and Euclidian coordinates (xx, yy) giving contextualize the physical demands on the tactical behaviour (Carrilho et al., 2020; Clemente et al., 2013; Low et al., 2020; Memmert et al., 2017). However, some of the above mentioned tracking methods do not allow to gather information about the player-ball-goal position (Carrilho et al., 2020; Vidal-Codina et al., 2022), opponent-adaptive play strategy (Memmert, 2021; Ranjitha et al., 2020) and individual tactical behavior (Laakso et al., 2022; Reis & Almeida, 2020).

Furthermore, the tracking systems generate a large quantity and variety of data that can be used for performance analysis in football contexts (Rein & Memmert, 2016; Rojas-Valverde et al., 2019). It is important implementing multidisciplinary frameworks between sports science and computer science based on big data methodology, using new computational procedures to extract,

process and analyse data with practical applicability for training and match performance (Rico-González et al., 2021). However, integrating players' physical performance with match-related contextual factors and tactical behaviours continues to represent a challenge for football science (Teixeira et al., 2022). Moreover, the performance analysis in football needs a multidimensional approach to capture the adaptive individual and collective behaviour (Carling et al., 2014; Gonçalves et al., 2019). These multifactorial phenomenon depends on a physical, tactical and technical factors with a not each performance factor is not mutually exclusive of one another (Bradley & Ade, 2018; Paul et al., 2015). Thus, performance analysis in football is now focused on applying the spatiotemporal parameters from an integrative perspective (Praça et al., 2022).

Currently, a growing reviews and meta-analysis have been published on this research topic focusing on training and match insights (Low et al., 2020; Rago et al., 2020; Teixeira et al., 2021). However, reviewing articles have considered each performance factor independently, describing tactical behaviour separately from physical demands (Coito et al., 2022; Ometto et al., 2018). It is therefore important to understand the main methodological procedures to conduct an integrative analysis of physical and tactical performance in football training and match. Also, the published studies have calculated different physical and tactical measures through tracking positional data, wherefore a procedural standardization is needed to progress towards integrative approaches (Teixeira et al., 2022). Thus, the aim of this study was to systematically review the published articles that integrate physical and tactical variables in football using positional data.

2. Methods

2.1. Literature Search strategy

The literature search strategy was registered at the International Platform of Registered Systematic Review and Meta-Analysis Protocols with the number 202270030 (doi: 10.37766/inplasy2022.7.0030). The protocol was designed in accordance with ‘The Preferred Reporting Items for Systematic Reviews and Meta-Analyses’ (PRISMA) guidelines and the ‘Population-Intervention-Comparators-Outcomes’ (PICOS) (Page et al., 2021). The literature search was based on three databases: PubMed/Medline, Web of Science (WoS, including all Web of Science Core Collection: Citation Indexes), and SportDiscus. The studies were searched using a Boolean search phrase with specific keywords (Table 1).

[PLACE TABLE 1 HERE]

The literature search was accessed between April and May 2022 by an independently author (J.E.T), and checked by a second author (P.F.). Discrepancies between the authors in the study selection were solved with support a third reviewer (T.M.B). Double-check review is recommended in PRISMA guidelines (Page et al., 2021). The literature search was limited to peer-reviewed articles and authors did not prioritize authors or journals.

2.2. Selection criteria

The selection criteria were conducted by the following PICOS approach: (1) *Population*: amateur, semi-professional and professional Football players (aged ≥ 10 years); (2) *Intervention*: integration of physical and tactical measures using spatiotemporal datasets; (3) *Comparison*: physical and tactical variables (4) *Outcomes*: tracking, positional and time-series data; (5) *Study design*: original

experimental and quasi-experimental trials (e.g., randomized controlled trial, cohort studies or cross-sectional studies).

On this basis, the inclusion criteria used for the article selection were: (1) original article focused on adult and youth football players of both sexes; (2) studies with screening procedures based on physical and tactical measures using tracking and positional data; (3) studies that used spatiotemporal to assess physical data; (4) studies that used positional and tracking data to measures spatiotemporal and tactical variables through time-series; (3) other performance factors as psychophysiological, technical and contextual factors were not excluded from the present review only if both variables of interest (i.e., physical and tactical measures) were also part of the experimental design; (5) studies of human physical performance in Sport Science and as scope; (6) original article published in a peer-review journal; (7) full text available in English; (8) article reported sample and screening procedures (e.g. data collection, study design, instruments, and the outcomes).

Otherwise, the exclusion criteria were: (1) original articles individual and others team sports as football code population (e.g. Australian Football, Gaelic Football, Union and/or Seven Rugby); (2) studies that study that analysed none or only one of the target performance factors (i.e. physical or tactical measures); (3) studies which integrate several performance factors, but do not combine the two variables of interest even if one of them is integrated; (4) studies that measured physical using on field based test and laboratory test rather than tracking and positional data; (5) studies that included tactical variables using notational analysis and other methodological procedures that do not assess spatiotemporal data through time-series; (6) others research areas and non-human participants; (7) articles with bad quality in the description of study sample and screening procedures (e.g. data collection, study design, instruments, and the measures) according

to PEDro and Downs and Black scales; (8) reviews, abstract/papers conference, surveys, opinion pieces, commentaries, books, periodicals, editorials, case studies, non-peer-reviewed text, masters and/or doctoral thesis.

2.3. Quality Assessment

The methodological quality was assessed using the modified Downs and Black Quality Index (cross-sectional studies) and the Physiotherapy Evidence Database (PEDro) scale (intervention studies) based on previous systematics reviews (Downs & Black, 1998; Maher et al., 2003). For cross-sectional studies, the modified Downs and Black Index is scored from a 14-item scale, with higher scores indicating higher quality studies. For intervention studies, the PEDro scale was assessed using a 6-item scale representing the cut-off values for high-quality studies (Bujalance-Moreno et al., 2019; García-Pinillos et al., 2017). Previous research have reported a good test–retest ($r = 0.58–0.88$) and inter-rater reliability ($r = 0.68$ to 0.75) for both qualitative indexes (Downs & Black, 1998; Maher et al., 2003). For this systematic review, the quality assessment was independently performed by two authors (J.E.T, P.F.) with subsequent inter-observer reliability analysis (Kappa index: 0.91; 95% IC: 0.90–0.92).

2.4. Study Coding and Data Extraction

The data extraction of the reviewed articles were organized into the following topics: (1) sampling characteristics by the study design, population, competitive level, sample (N), sex, age, expertise level and quality score (Table 2); (2) summary of performance dimension, measures, measurement, thresholds and/or metric formula in the reviewed articles; references and ‘further reading’ reports the original studies where the methodology of the included articles were based; (3) methodological

approaches of the reviewed studies by reporting the study purpose, experimental approach, methodological procedures, data collection, statistical and mathematical analysis. Data were collected as previously described in ‘The Cochrane Data Extraction Template for Included Studies’ using a Microsoft Excel sheet (Microsoft Corporation, Readmon, WA, USA (Synnot et al., 2020)).

3. Results

3.1. Search Results and Study Selection

A total of 982 titles were collected through three database searches (WoS = 495; Pub-Med = 232 and SportDiscus = 255). After applying the selection criteria, 153 full-text articles were assessed for eligibility, having selected 26 articles for final revision. Figure 1 showed the search results using PRISMA flow diagram with screening procedures and search results.

[PLACE FIGURE 1 HERE]

3.2. Participant Characteristics

The reviewed articles were published between 2000 and 2022. Studies samples were ranged between 8–148 participants with an observational, prospective and cross-sectional design ($n = 8$) and randomized controlled trial ($n = 18$). Twenty-three articles were focused on adult football players and seven on youth population. All articles were performed on male football players, specifically in elite ($n = 2$), professional ($n = 8$), high-level ($n = 1$), national level ($n = 2$), amateur ($n = 2$) and volunteer ($n = 1$) contexts. A total of 538 football players were analysed in this systematic review. Age and expertise level in the included studies was 16.81 ± 1.63 and 4.2 ± 3.83 years, respectively. Table 2 provides the sampling characteristics of the reviewed studies.

[PLACE TABLE 2 HERE]

3.3. Quality Assessment

In the evaluation of methodological quality, the qualitative scores for cross-sectional studies ranged from 8 (lowest quality) to 11 (highest quality) within a maximum of 14 in Downs and Black scale (Table 3). For intervention studies, the PEDro score ranged from 6 (lowest quality) to 9 (lowest quality) within a maximum of 11 (Table 4).

[PLACE TABLE 3 HERE]

[PLACE TABLE 4 HERE]

3.4. Main Findings

Table 5 presented the data extraction of the reviewed studies. Concerning the physical data, the external training load measures considered were based on movement speed) specifically: (i) total distance covered ($n = 11$), (ii) distance covered at different speed zones ($n = 13$), (iii) game pace or average speed ($n = 3$), (iv) accelerations and decelerations ($n = 3$), (v) locomotive-based ratios (e.g., ratio between the distance covered at different intensities and distance) ($n = 1$). Otherwise, positional and tactical variables reported in the included studies was based on the following independent variables: (i) possession ball ($n = 1$), (ii) spatial exploration indexes ($n = 6$), (iii) LPW ratio ($n = 1$), (iv) stretch indexes ($n = 2$), (v) multiscale entropy ($n = 1$), (vi) synchronization indexes (i.e., longitudinal and lateral directions) ($n = 10$), (v) intra-team and opponent's dyads ($n = 3$), (vi) dispersion and contraction indexes (i.e., length, width and speed) ($n = 4$), (vii) playing space and effectiveness (i.e., effective playing space, longitudinal distance between GK and the closest defender ($n = 3$), (viii) player's variability, regularity and coordination ($n = 10$) (i.e., entropy, dynamic overlap, near-in-phase and near-anti-phase coordination, regularity zones occupied), (ix) team centroid ($n = 2$).

Table 6 showed the study purpose, game format, experimental approach, methodological procedures, data collection, statistical and mathematical analysis of the included studies in this review. The data organization respected the main purposes of this systematic review, specifically the integration of physical and tactical variables in football using positional data ($n = 26$). Other dimensions were also reported, such as psychological and technical factors, however the results of these approaches were not the focus of the analysis ($n = 5$). Specifically, non-positional variables were computed by the reviewed studies for other performance dimension such as technical ($n = 4$), tactical ($n = 5$) and psychophysiological variables ($n = 4$). Specifically, the psychophysiological were reported by exertion-based indexes (i.e., exertion index per minute, ratings of perceived exertion) ($n = 1$) and (vii) heart rate-based methods (i.e., %HR_{max}, TRIMP_{MOD}) ($n = 3$).

Quasi-experimental approaches considered training sets ($n = 20$) and match contexts ($n = 6$). One study analysed both training and play insights. Small sided-games (SSG) were the most common training task formats in the reviewed studies ($n = 17$), with only three articles addressing medium-sided (MSG) ($n = 1$) and large-sided games (LSG) ($n = 4$), respectively. Regarding the methodological procedures, Matlab® routines (Math-Works, Inc., Massachusetts, USA) were used by all authors for processing raw data (xx, yy) ($n = 26$). All studies applied Butterworth low pass filter at frequency sampling ranged between 3–5 Hz using 10–20 windows and 1000–3000 points per data collect. Match analysis software were applied for to extract technical variables into three studies, specifically the LongoMatch® software ($n = 1$), Match Analysis Camera Systems® ($n = 1$) and Lince software ($n = 1$). Data collection was based on GPS ($n = 15$), LPM ($n = 2$) and optical-based tracking systems ($n = 5$) ranging from 5 to 15 Hz. Also, internal training load measures was collected by 1 Hz short-range radio telemetry ($n = 2$) and CR 10-scale ($n = 1$). A study used

portable optical timing system to measure neuromuscular performance (i.e., countermovement jump, CMJ).

A null hypothesis statistical test (NHST) and magnitude-based inferences (MBI) in seven studies ($n = 7$) and five studies ($n = 5$), respectively. The statistical and mathematical analysis performed in the reviewed reports were the approximate entropy (ApEn) ($n = 7$), Boltzmann–Gibbs–Shannon entropy measure ($n = 7$), Coefficient of variation (CV) ($n = 7$), dynamic overlap ($\langle qd(t) \rangle$) ($n = 7$), effect sized Cohen d ($n = 7$), effect sized eta-squared (η_p^2) ($n = 7$), hilbert transform ($n = 7$), intraclass correlation (ICC) ($n = 7$), smallest worthwhile changes (SWC) ($n = 7$), standard error of measurement (SEM) ($n = 7$), standardized (Cohen) differences ($n = 7$), structural coefficients (SC) ($n = 7$), and trapping strength ($n = 7$).

[PLACE TABLE 5 HERE]

[PLACE TABLE 6 HERE]

4. Discussion

The aim of this study was to systematically review the published articles that integrate physical and tactical variables in football using positional data. Earliest, the physical data was analysed by the player's movement speed. Otherwise, positional datasets was computed by spatiotemporal features such as spatial variability or regularity of the player's movements, complex index, coordination/synchronization using intra-team and inter-team dyads, playing space.

Positional datasets allows a more ecological approach to individual physical demands, if the data interpretation considers the contextual factors and collective behaviour through a tactical analysis (Marcelino et al., 2020; Teixeira et al., 2022; Teixeira et al., 2021). As well, several authors have emphasized the need to recklessness the one-dimensional research. It is important to apply methodologies based on integrative approaches that analyse the interdependence between technical factors, key tactical/performance indicators, collective behaviour and match-related contextual factors (Teixeira et al., 2022). Therefore, an integrative approach was extended in 8 articles by adding psychophysiological and technical outcomes (Bradley & Ade, 2018; Paul et al., 2015). Considering the multifactoriality of performance in team sports as football, it is also important to consider the influence of psychological variables on the control of physical capacities, pacing behaviour, decision-making, self-regulation, and effort perception (Branquinho et al., 2020, 2021; Ferraz et al., 2022). Also, the bringing together of observational methodologies should be considered when positional data is to be made meaningful with skilled and technical aspects (Anguera & Mendo, 2013; Preciado et al., 2019; Sarmiento et al., 2018).

Moreover, the reviewed quasi-experimental approaches considered training sets and match contexts. Small sided-games (SSG) were the most common training task formats in the reviewed studies, with only three articles addressing medium-sided (MSG) and large-sided games (LSG) (Machado et al., 2020; Folgado et al., 2018; Gonçalves et al., 2017; Jara et al., 2019; Nieto et al.,

2022; Praça et al., 2016), respectively. Thus, the SSG formats have been further explored in the literature, mainly through the 5- and 6-sided game format. Indeed, these SSG-based formats was previous reported as an useful tool to promote into significant variations in the training load, and in the likely improvement of the different domains of soccer training (i.e., physiological, technical, and tactical dimensions) (Branquinho & Marques, 2021; Clemente et al., 2021). Also, SSG and conditioned games (SSCG) are an excellent form to enhance acquisition of motor efficiency and decision-making skills (Davids et al., 2013). A widespread research gap remains unexplored in MSG and LSG formats, as well as their relationship with formal game formats (i.e., 7-, 8-, 9- and 11-sided formats) (Baptista et al., 2020; Coutinho et al., 2019, 2020; Ferraz et al., 2020; Figueira et al., 2018; Gonçalves et al., 2017; Sampaio et al., 2014).

Regarding the methodological procedures, Matlab® routines (Math-Works, Inc., Massachusetts, USA) were applied to process raw data (xx, yy) ($n = 26$), transforming data points in the Universal Transverse Mercator (UTM) coordinate system (Folgado et al., 2014; Sampaio & Maças, 2012). The most used correction guidelines to reduce tracking signal noise was a 3 Hz Butterworth low pass filter by applying a non-linear logarithms using 20 windows of 3000 points per data collect (Coutinho et al., 2019, 2020; Figueira et al., 2018; Folgado et al., 2015, 2019; Gonçalves et al., 2017, 2018). Other studies used smaller data windows such as 1500 data sets and a sampling frequency for signal correction (i.e., 5Hz) (Baptista et al., 2020). Nevertheless, the sampling frequency and datasets is highly dependent on the type of non-linear method to be used, and the use of higher time-series lengths can increase the consistency of the positional data (Baptista et al., 2020; Richman & Moorman, 2000; Yentes et al., 2013). Approximate entropy (ApEn) was the most applied non-linear method for measuring the spatial movement variability/regularity (Baptista et al., 2020; Coutinho et al., 2019, 2020; Ferraz et al., 2020;

Figueira et al., 2018; Gonçalves et al., 2017; Sampaio et al., 2014). Also, stretch index can be based on the ApEn or distance, being the most reported complex index in the reviewed literature (Coutinho et al., 2019; Olthof et al., 2018; Praça et al., 2021). Indeed, the entropy has been extensively reported as outstanding informational parameter to describe the variability and predictability of the players' movement (Teixeira et al., 2022). Hilbert transform was the most frequent method, by computing the longitudinal and lateral directions through in- and anti-phase (Coutinho et al., 2019, 2020; Fernandes et al., 2010; Figueira et al., 2018; Folgado et al., 2015, 2019; Gonçalves et al., 2017, 2018). Total surface area or playing space (m^2) can be provided through trigonometry using the smallest convex hull and/or polygonal area delimited by the peripheral players (Coutinho et al., 2017; Folgado et al., 2019; Olthof et al., 2018). Recently, Teixeira et al. (2022) reported what remains to be explored correlation matrixes, clustering methods and fractality patterns. This review confirms this and opens up the possibility of exploring these metrics by integrating physical demands with individual and collective behaviour.

Match analysis software were applied in reviewed three studies for notational analysis to extract technical variables, specifically the LongoMatch® software, Match Analysis Camera Systems® (Gonçalves et al., 2018) and Lince software® (Canton et al., 2021; Ric et al., 2016). Further tactical variables was applied in the reviewed studies using other methodological approaches (i.e., observational and notational analysis) such as metrics based on ball possession, team networks and tactical actions classifications. Technical outcomes were mainly based on individual actions and skills characterized in quantity and success (i.e., successful passes, dribbles and shots) (Coutinho et al., 2020, 2022a; 2022b; 2022c; Folgado et al., 2019; Olthof et al., 2018; Ric et al., 2017). Data collection was based on GPS, LPM and optical-based tracking systems ranging from 5 to 18 Hz. The first studies were mainly based on 5 Hz GPS (SPI-Pro X II, GPS

ports, Canberra, ACT, and Australia), however the use of sampling frequency at 5Hz must consider some limitations in the measurement of non-linear and high-intensity paths (Portas et al., 2010; Teixeira et al., 2021). Authors should prioritise tracking devices with sampling frequencies above 10 Hz shape with an accelerometer (Gómez-Carmona et al., 2020; Rico-González et al., 2020). The latest GPS devices already recommend a sampling frequency of 10-18Hz, specifically 10 Hz GPS units (WIMU PRO, RealTrack Systems, Almeria, Spain) (Canton et al., 2021; Machado et al., 2022), 10 Hz GPS (S5, Catapult Innovations, Australia) (Folgado et al., 2019; Nieto et al., 2022), 10 Hz GPS (Polar, Team Pro, Kempele, Finland) (G. M. Praça et al., 2021), 15Hz GPS (SPIPRO, GPSports, Canberra, ACT, Australia) (Coutinho et al., 2017; Praça et al., 2016; Ric et al., 2016) and 18.18 Hz GPS (GPEXE GK, Exelio SRL, Udine, Italy) (Jara et al., 2019). LPM devices and semiautomatic video tracking system used in the surveyed studies were the Prozone[®] (ProZone Holdings Ltd, UK) (Folgado et al., 2015) and the Inmotio Object Tracking[®] (BV., Amsterdam, the Netherlands) (Olthof et al., 2018). The integration of the different tracking systems can be further explored from an integrative perspective (Buchheit et al., 2014; Linke et al., 2018). Also, the relationship between objective (i.e., tracking systems) and subjective (i.e., observational/notational analysis) measures should be explored in future integrative approaches, in order to make the integration of technical and tactical factors more effective (Teixeira et al., 2021b). Indeed, the non-positional data can act as a complement to the positional raw data by making the information gathered from the tracking systems more viable and richer (Praça et al., 2022, Teixeira et al., 2021b)

Likewise, internal training load was collected by heart-rate-based measures and perceived exertion. Although some limitations have been reported in some studies, the perceived exertion and heart-rate maintains its applicability for elite and sub-elite football contexts, and is lower cost

and more easily implemented (Achten & Jeukendrup, 2003; Teixeira et al., 2022; Teixeira, Forte, et al., 2021b). A study used portable optical timing system to measure neuromuscular performance (i.e., countermovement jump, CMJ). The field-based tests in football becomes more effective when continuous control (i.e. monitoring) is integrated into the assessment (Clemente et al., 2022; Gomez-Carmona et al., 2020).

A null hypothesis statistical test (NHST) and magnitude-based inferences (MBI) in seven studies and five studies, respectively. Some authors used joint approaches for their data handling, as well as statistical analysis such as coefficient of variation (CV) ($n = 7$), effect sized (ES) and smallest worthwhile changes (SWC) (Bernards et al., 2017; Flanagan, 2013). The application of the two statistical approaches makes it more difficult to compare results of the availed studies, and future studies should further analyse the potential overvaluation and bias of the study findings (Foster et al., 2017; Welsh & Knight, 2015). Bringing NHST and MBI approaches together may be a valid approach to avoid overestimating outcomes (Welsh & Knight, 2015).

The current systematic review has some limitations should be consider. First, the interpretation of the studies was only qualitative, not considering meta-analysis. Second, the fact that only studies that integrated the physical and tactical measures and not just one dimension. For this reason, other information about physical and behavioural data may have been absent (Duarte et al., 2013; Folgado et al., 2014; Vilar et al., 2014). Although this was made objective in the inclusion and exclusion criteria, future systematic reviews should clarify which studies used both one-dimensional and integrative approach. As practical applications and futures researches, there are some future topics that could be explored specifically: (i) the development of friendly-user interfaces, in order to disseminate positional data until now almost exclusively to Matlab® routines processing (Math-Works, Inc., Massachusetts, USA); (ii) developing tracking and wearables

devices which enable real-time feedback to increase the practical applicability and decision making of football players and coaching staff; (iii) applying advanced data analytics and big data-based methods using artificial intelligence (AI), machine learning (ML) and deep learning to compute automatically physical and positional data; (iv) manipulating task constraints in MSG, LSG and different game-formats can still be better exploited; woman's football is still not analysed using physical and tactical integration.

5. Conclusions

Among the current systematic review, the physical and tactical factors can be integrated by positional data using player's movement speed, spatial movement (and their variability, regularity or predictability), complex indexes, playing areas, intra-team and inter-team synchronization dyads. Futures research should consider applying positional data in women's football and explore the representativeness of the MSG and LSG in youth training environments. Although positional data is being extensively applied in semi-professional and professional football, forthcoming challenge focuses on the development of friendly-user and real-time interfaces to integrate physical and tactical measures

6. References

- Abade, E. A., Gonçalves, B. V., Leite, N. M., & Sampaio, J. E. (2014). Time-motion and physiological profile of football training sessions performed by under-15, under-17 and under-19 elite Portuguese players. *International Journal of Sports Physiology and Performance*, 9(3), 463–470. <https://doi.org/10.1123/ijsp.2013-0120>
- Abt, G., & Lovell, R. (2009). The use of individualized speed and intensity thresholds for determining the distance run at high-intensity in professional soccer. *Journal of Sports Sciences*, 27(9), 893–898. <https://doi.org/10.1080/02640410902998239>
- Achten, J., & Jeukendrup, A. E. (2003). Heart rate monitoring: Applications and limitations. *Sports Medicine (Auckland, N.Z.)*, 33(7), 517–538.
- Anguera, M. T., & Hernández Mendo, A. (2013). *Observational methodology in sport sciences*. <https://dehesa.unex.es:8443/handle/10662/7361>
- Arede, J., Cumming, S., Johnson, D., & Leite, N. (2021). The effects of maturity matched and un-matched opposition on physical performance and spatial exploration behavior during youth basketball matches. *PLOS ONE*, 16(4), e0249739. <https://doi.org/10.1371/journal.pone.0249739>
- Balescu, R. (1975). Equilibrium and nonequilibrium statistical mechanics. *NASA STI/Recon Technical Report A*, 76, 32809.
- Baptista, J., Travassos, B., Gonçalves, B., Mourão, P., Viana, J. L., & Sampaio, J. (2020). Exploring the Effects of Playing Formations on Tactical Behavior and External Workload During Football Small-Sided Games. *The Journal of Strength & Conditioning Research*, 34(7), 2024–2030. <https://doi.org/10.1519/JSC.0000000000002445>
- Batshchelet, E. (1981). *Circular Statistics in Biology*. Academic Press, 111 Fifth ave., New York, NY.
- Beato, M., Coratella, G., Stiff, A., & Iacono, A. D. (2018). The validity and between-unit variability of GNSS units (STATSports Apex 10 and 18 Hz) for measuring distance and peak speed in team sports. *Frontiers in Physiology*, 9. <https://doi.org/10.3389/fphys.2018.01288>
- Beato, M., & Jamil, M. (2018). Intra-system reliability of SICS: Video-tracking system (Digital.Stadium®) for performance analysis in soccer. *The Journal of Sports Medicine and Physical Fitness*, 58(6), 831–836. <https://doi.org/10.23736/S0022-4707.17.07267-X>
- Bernards, J. R., Sato, K., Haff, G. G., & Bazyler, C. D. (2017). Current Research and Statistical Practices in Sport Science and a Need for Change. *Sports*, 5(4), 87. <https://doi.org/10.3390/sports5040087>
- Bourbousson, J., Sève, C., & McGarry, T. (2010). Space–time coordination dynamics in basketball: Part 2. The interaction between the two teams. *Journal of Sports Sciences*, 28(3), 349–358. <https://doi.org/10.1080/02640410903503640>
- Bradley, P., & Ade, J. (2018). Are current physical match performance metrics in elite soccer fit for purpose or is the adoption of an integrated approach needed? *International Journal of Sports Physiology and Performance*, 13(5), 656–664. <https://doi.org/10.1123/ijsp.2017-0433>
- Bradley, P. S., & Ade, J. D. (2018). Are current physical match performance metrics in elite soccer fit for purpose or is the adoption of an integrated approach needed? *International Journal of Sports Physiology and Performance*, 13(5), 656–664. <https://doi.org/10.1123/ijsp.2017-0433>
- Branquinho, L., Ferraz, R., & Marques, M. C. (2021). 5-a-Side Game as a Tool for the Coach in Soccer Training. *Strength and Conditioning Journal*, 43(5), 96–108. <https://doi.org/10.1519/SSC.0000000000000629>
- Branquinho, L., Ferraz, R., Travassos, B., Marinho, D. A., & Marques, M. C. (2021). Effects of different recovery times on internal and external load during small-sided games in soccer. *Sports Health*, 1941738121995469. <https://doi.org/10.1177/1941738121995469>
- Branquinho, L., Ferraz, R., Travassos, B., & Marques, M. C. (2020). Comparison between continuous and fractionated game format on internal and external load in small-sided games in soccer. *International Journal of Environmental Research and Public Health*, 17(2), 405. <https://doi.org/10.3390/ijerph17020405>

- Buchheit, M., Allen, A., Poon, T. K., Modonutti, M., Gregson, W., & Salvo, V. D. (2014). Integrating different tracking systems in football: Multiple camera semi-automatic system, local position measurement and GPS technologies. *Journal of Sports Sciences*, 32(20), 1844–1857. <https://doi.org/10.1080/02640414.2014.942687>
- Busa, M. A., & van Emmerik, R. E. A. (2016). Multiscale entropy: A tool for understanding the complexity of postural control. *Journal of Sport and Health Science*, 5(1), 44–51. <https://doi.org/10.1016/j.jshs.2016.01.018>
- Campos-Vazquez, M. A., Mendez-Villanueva, A., Gonzalez-Jurado, J. A., León-Prados, J. A., Santalla, A., & Suarez-Arrones, L. (2015). Relationships between rating-of-perceived-exertion- and heart-rate-derived internal training load in professional soccer players: A comparison of on-field integrated training sessions. *International Journal of Sports Physiology and Performance*, 10(5), 587–592. <https://doi.org/10.1123/ijspp.2014-0294>
- Canton, A., Torrents, C., Gonçalves, B., Ric, A., Salvioni, F., Exel, J., & Sampaio, J. (2021). The diagonal positioning of the goals modifies the external training load and the tactical behaviour of young football players. *Biology of Sport*, 39(1), 135–144. <https://doi.org/10.5114/biolsport.2021.102929>
- Carling, C., Wright, C., Nelson, L. J., & Bradley, P. S. (2014). Comment on ‘Performance analysis in football: A critical review and implications for future research’. *Journal of Sports Sciences*, 32(1), 2–7. <https://doi.org/10.1080/02640414.2013.807352>
- Carrilho, D., Santos Couceiro, M., Brito, J., Figueiredo, P., Lopes, R. J., & Araújo, D. (2020). Using Optical Tracking System Data to Measure Team Synergic Behavior: Synchronization of Player-Ball-Goal Angles in a Football Match. *Sensors*, 20(17), 4990. <https://doi.org/10.3390/s20174990>
- Castellano, J., Alvarez-Pastor, D., & Bradley, P. S. (2014). Evaluation of research using computerised tracking systems (Amisco and Prozone) to analyse physical performance in elite soccer: A systematic review. *Sports Medicine (Auckland, N.Z.)*, 44(5), 701–712. <https://doi.org/10.1007/s40279-014-0144-3>
- Clemente, F. M., Afonso, J., Castillo, D., Arcos, A. L., Silva, A. F., & Sarmento, H. (2020). The effects of small-sided soccer games on tactical behavior and collective dynamics: A systematic review. *Chaos, Solitons & Fractals*, 134, 109710. <https://doi.org/10.1016/j.chaos.2020.109710>
- Clemente, F. M., Afonso, J., & Sarmento, H. (2021). Small-sided games: An umbrella review of systematic reviews and meta-analyses. *PLOS ONE*, 16(2), e0247067. <https://doi.org/10.1371/journal.pone.0247067>
- Clemente, F. M., Couceiro, M. S., Martins, F. M. L., Mendes, R., & Figueiredo, A. J. (2013). Measuring tactical behaviour using technological metrics: Case study of a football game. *International Journal of Sports Science & Coaching*, 8(4), 723–739. <https://doi.org/10.1260/1747-9541.8.4.723>
- Clemente, F. M., Owen, A., Mustapha, A., van der Linden, C. M. I. (Niels), Ribeiro, J., Mendes, B., & Reichert, J. (2018). Measurement of the Pitch Exploration Amongst Elite Professional Soccer Players: Official Match Analysis. In R. Ghazali, M. M. Deris, N. M. Nawi, & J. H. Abawajy (Eds.), *Recent Advances on Soft Computing and Data Mining* (pp. 191–199). Springer International Publishing. https://doi.org/10.1007/978-3-319-72550-5_19
- Clemente, F. M., Owen, A., Serra-Olivares, J., Correia, A., Bernardo Sequeiros, J., Silva, F. G., & Martins, F. M. L. (2018). The effects of large-sided soccer training games and pitch size manipulation on time–motion profile, spatial exploration and surface area: Tactical opportunities. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 232(2), 160–165. <https://doi.org/10.1177/1754337117722658>
- Clemente, F., Oliveira, R., Akyildiz, Z., Silva, R., Ceylan, H., Afonso, J., & Raya-González, J. (2022). *Field-based Tests for Soccer Players: Methodological Concerns and Applications*.
- Coito, N., Davids, K., Folgado, H., Bento, T., & Travassos, B. (2022). Capturing and Quantifying Tactical Behaviors in Small-Sided and Conditioned Games in Soccer: A Systematic Review. *Research Quarterly for Exercise and Sport*, 93(1), 189–203. <https://doi.org/10.1080/02701367.2020.1823307>
- Collet, C. (2013). The possession game? A comparative analysis of ball retention and team success in European and international football, 2007–2010. *Journal of Sports Sciences*, 31(2), 123–136. <https://doi.org/10.1080/02640414.2012.727455>

- Costa, I. T. da, Garganta, J., Greco, P. J., Mesquita, I., & Maia, J. (2011). Sistema de avaliação táctica no Futebol (FUT-SAT): Desenvolvimento e validação preliminar. *Motricidade*, 7(1), 69–84. <https://doi.org/10.6063/motricidade.121>
- Costa, M., Goldberger, A. L., & Peng, C.-K. (2005). Multiscale entropy analysis of biological signals. *Physical Review E*, 71(2), 021906. <https://doi.org/10.1103/PhysRevE.71.021906>
- Coutinho, D., Gonçalves, B., Folgado, H., Travassos, B., Santos, S., & Sampaio, J. (2022a). Amplifying perceptual demands: How changes in the colour vests affect youth players performance during medium-sided games. *PLOS ONE*, 17(1), e0262245. <https://doi.org/10.1371/journal.pone.0262245>
- Coutinho, D., Gonçalves, B., Santos, S., Travassos, B., Folgado, H., & Sampaio, J. (2022b). Exploring how limiting the number of ball touches during small-sided games affects youth football players' performance across different age groups. *International Journal of Sports Science & Coaching*, 17(3), 545–557. <https://doi.org/10.1177/17479541211037001>
- Coutinho, D., Gonçalves, B., Santos, S., Travassos, B., Schöllhorn, W., & Sampaio, J. (2022c). The effects of individual and collective variability on youth players' movement behaviours during football small-sided games. *Research in Sports Medicine*, 0(0), 1–16. <https://doi.org/10.1080/15438627.2022.2042293>
- Coutinho, D., Gonçalves, B., Santos, S., Travassos, B., Wong, D. P., & Sampaio, J. (2019). Effects of the pitch configuration design on players' physical performance and movement behaviour during soccer small-sided games. *Research in Sports Medicine*, 27(3), 298–313. <https://doi.org/10.1080/15438627.2018.1544133>
- Coutinho, D., Gonçalves, B., Travassos, B., Abade, E., Wong, D. P., & Sampaio, J. (2019). Effects of pitch spatial references on players' positioning and physical performances during football small-sided games. *Journal of Sports Sciences*, 37(7), 741–747. <https://doi.org/10.1080/02640414.2018.1523671>
- Coutinho, D., Gonçalves, B., Travassos, B., Folgado, H., Figueira, B., & Sampaio, J. (2020). Different marks in the pitch constraint youth players' performances during football small-sided games. *Research Quarterly for Exercise and Sport*, 91(1), 15–23. <https://doi.org/10.1080/02701367.2019.1645938>
- Coutinho, D., Gonçalves, B., Travassos, B., Wong, D. P., Coutts, A. J., & Sampaio, J. E. (2017). Mental fatigue and spatial references impair soccer players' physical and tactical performances. *Frontiers in Psychology*, 0. <https://doi.org/10.3389/fpsyg.2017.01645>
- Coutts, A. J., & Duffield, R. (2010). Validity and reliability of GPS devices for measuring movement demands of team sports. *Journal of Science and Medicine in Sport*, 13(1), 133–135. <https://doi.org/10.1016/j.jsams.2008.09.015>
- Dalen, T., Jørgen, I., Gertjan, E., Geir Havard, H., & Ulrik, W. (2016). Player load, acceleration, and deceleration during forty-five competitive matches of elite soccer. *The Journal of Strength & Conditioning Research*, 30(2), 351–359. <https://doi.org/10.1519/JSC.0000000000001063>
- David Gomez-Carmona, C., Pino-Ortega, J., & Jose Ibanez, S. (2020). Design and validity of a field test battery for assessing multi-location external load profile in invasion team sports. *E-Balónmano Com*, 16(1), 23–48.
- Davids, K., Araújo, D., Correia, V., & Vilar, L. (2013). How Small-Sided and Conditioned Games Enhance Acquisition of Movement and Decision-Making Skills. *Exercise and Sport Sciences Reviews*, 41(3), 154–161. <https://doi.org/10.1097/JES.0b013e318292f3ec>
- Di Salvo, C., & Marco, C. (2006). Validation of Prozone ®: A new video-based performance analysis system. *International Journal of Performance Analysis in Sport*, 6(1), 108–119. <https://doi.org/10.1080/24748668.2006.11868359>
- Duarte, R., Araújo, D., Correia, V., & Davids, K. (2012). Sports teams as superorganisms: Implications of sociobiological models of behaviour for research and practice in team sports performance analysis. *Sports Medicine*, 42(8), 633–642. <https://doi.org/10.1007/BF03262285>
- Duarte, R., Araújo, D., Correia, V., Davids, K., Marques, P., & Richardson, M. J. (2013). Competing together: Assessing the dynamics of team–team and player–team synchrony in professional association football. *Human Movement Science*, 32(4), 555–566. <https://doi.org/10.1016/j.humov.2013.01.011>

- Duarte, R., Araújo, D., Davids, K., Travassos, B., Gazimba, V., & Sampaio, J. (2012). Interpersonal coordination tendencies shape 1-vs-1 sub-phase performance outcomes in youth soccer. *Journal of Sports Sciences*, 30(9), 871–877. <https://doi.org/10.1080/02640414.2012.675081>
- Duarte, R., Araújo, D., Folgado, H., Esteves, P., Marques, P., & Davids, K. (2013). Capturing complex, non-linear team behaviours during competitive football performance. *Journal of Systems Science and Complexity*, 26(1), 62–72. <https://doi.org/10.1007/s11424-013-2290-3>
- Duarte, R., Araújo, D., Freire, L., Folgado, H., Fernandes, O., & Davids, K. (2012). *Intra- and inter-group coordination patterns reveal collective behaviors of football players near the scoring zone.* <https://doi.org/10.1016/j.humov.2012.03.001>
- Fernandes, O., Folgado, H., Duarte, R., & Malta, P. (2010). Validation of the tool for applied and contextual time-series observation. *International Journal of Sport Psychology*, 41, 63–64.
- Ferraz, R., Forte, P., Branquinho, L., Teixeira, J., Neiva, H., Marinho, D., & Marques, M. (2022). *The Performance during the Exercise: Legitimizing the Psychophysiological Approach.* <https://doi.org/10.5772/intechopen.102578>
- Ferraz, R., Gonçalves, B., Coutinho, D., Marinho, D. A., Sampaio, J., & Marques, M. C. (2018). Pacing behaviour of players in team sports: Influence of match status manipulation and task duration knowledge. *PLoS One*, 13(2), e0192399. <https://doi.org/10.1371/journal.pone.0192399>
- Ferraz, R., Gonçalves, B., Coutinho, D., Oliveira, R., Travassos, B., Sampaio, J., & Marques, M. C. (2020). Effects of knowing the task's duration on soccer players' positioning and pacing behaviour during small-sided games. *Int. J. Environ. Res. Public Health*, 11.
- Ferraz, R., Gonçalves, B., Tillaar, R., Saiz, S., Sampaio, J., & Marques, M. (2017). Effects of knowing the task duration on players' pacing patterns during soccer small-sided games. *Journal of Sports Sciences*, 36. <https://doi.org/10.1080/24733938.2017.1283433>
- Figueira, B., Gonçalves, B., Masiulis, N., & Sampaio, J. (2018). Exploring how playing football with different age groups affects tactical behaviour and physical performance. *Biology of Sport*, 35(2), 145–153. <https://doi.org/10.5114/biolsport.2018.71603>
- Flanagan, E. P. (2013). The Effect Size Statistic—Applications for the Strength and Conditioning Coach. *Strength & Conditioning Journal*, 35(5), 37–40. <https://doi.org/10.1519/SSC.0b013e3182a64d20>
- Folgado, H., Bravo, J., Pereira, P., & Sampaio, J. (2019). Towards the use of multidimensional performance indicators in football small-sided games: The effects of pitch orientation. *Journal of Sports Sciences*, 37(9), 1064–1071. <https://doi.org/10.1080/02640414.2018.1543834>
- Folgado, H., Duarte, R., Fernandes, O., & Sampaio, J. (2014). Competing with lower level opponents decreases intra-team movement synchronization and time-motion demands during pre-season soccer matches. *PloS One*, 9(5), e97145. <https://doi.org/10.1371/journal.pone.0097145>
- Folgado, H., Duarte, R., Marques, P., & Sampaio, J. (2015). The effects of congested fixtures period on tactical and physical performance in elite football. *Journal of Sports Sciences*, 33(12), 1238–1247. <https://doi.org/10.1080/02640414.2015.1022576>
- Folgado, H., Gonçalves, B., & Sampaio, J. (2018). Positional synchronization affects physical and physiological responses to preseason in professional football (soccer). *Research in Sports Medicine*, 26(1), 51–63. <https://doi.org/10.1080/15438627.2017.1393754>
- Folgado, H., Lemmink, K. A. P. M., Frencken, W., & Sampaio, J. (2014). Length, width and centroid distance as measures of teams tactical performance in youth football. *European Journal of Sport Science*, 14 Suppl 1, S487–492. <https://doi.org/10.1080/17461391.2012.730060>
- Fonseca, S., Milho, J., Travassos, B., & Araújo, D. (2012). Spatial dynamics of team sports exposed by Voronoi diagrams. *Human Movement Science*, 31(6), 1652–1659. <https://doi.org/10.1016/j.humov.2012.04.006>
- Foster, C., Rodriguez-Marroyo, J., & de Koning, J. (2017). Monitoring Training Loads: The Past, the Present, and the Future. *International Journal of Sports Physiology and Performance*, 12, 2–8.

- Frencken, W., De Poel, H., Visscher, C., & Lemmink, K. A. P. M. (2012). Variability of inter-team distances associated with match events in elite-standard soccer. *Journal of Sports Sciences*, 30, 1207–1213. <https://doi.org/10.1080/02640414.2012.703783>
- Frencken, W., Lemmink, K., Delleman, N., & Visscher, C. (2011). Oscillations of centroid position and surface area of soccer teams in small-sided games. *European Journal of Sport Science*, 11(4), 215–223. <https://doi.org/10.1080/17461391.2010.499967>
- Gabin, B., Camerino, O., Anguera, M. T., & Castañer, M. (2012). Lince: Multiplatform Sport Analysis Software. *Procedia - Social and Behavioral Sciences*, 46, 4692–4694. <https://doi.org/10.1016/j.sbspro.2012.06.320>
- García-Pinillos, F., Soto-Hermoso, V. M., & Latorre-Román, P. A. (2017). How does high-intensity intermittent training affect recreational endurance runners? Acute and chronic adaptations: A systematic review. *Journal of Sport and Health Science*, 6(1), 54–67. <https://doi.org/10.1016/j.jshs.2016.08.010>
- Giménez, J. V., Del-Coso, J., Leicht, A. S., & Gomez, M.-Á. (2018). Comparison of the movement patterns between small- and large-sided game training and competition in professional soccer players. *The Journal of Sports Medicine and Physical Fitness*, 58(10), 1383–1389. <https://doi.org/10.23736/S0022-4707.17.07343-1>
- Gómez-Carmona, C. D., Bastida-Castillo, A., Ibáñez, S. J., & Pino-Ortega, J. (2020). Accelerometry as a method for external workload monitoring in invasion team sports. A systematic review. *PLOS ONE*, 15(8), e0236643. <https://doi.org/10.1371/journal.pone.0236643>
- Gonçalves, B., Coutinho, D., Exel, J., Travassos, B., Peñas, C., & Sampaio, J. (2019). Extracting spatial-temporal features that describe a team match demands when considering the effects of the quality of opposition in elite football. *PLOS ONE*, 14, e0221368. <https://doi.org/10.1371/journal.pone.0221368>
- Gonçalves, B., Coutinho, D., Travassos, B., Folgado, H., Caixinha, P., & Sampaio, J. (2018). Speed synchronization, physical workload and match-to-match performance variation of elite football players. *PloS One*, 13(7), e0200019. <https://doi.org/10.1371/journal.pone.0200019>
- Gonçalves, B., Esteves, P., Folgado, H., Ric, A., Torrents, C., & Sampaio, J. (2017). Effects of pitch area-restrictions on tactical behavior, physical, and physiological performances in soccer large-sided games. *The Journal of Strength & Conditioning Research*, 31(9), 2398–2408. <https://doi.org/10.1519/JSC.0000000000001700>
- Gonçalves, B., Folgado, H., Coutinho, D., Marcelino, R., Wong, D., Leite, N., & Sampaio, J. (2018). Changes in Effective Playing Space when Considering Sub-Groups of 3 to 10 Players in Professional Soccer Matches. *Journal of Human Kinetics*, 62, 145–155. <https://doi.org/10.1515/hukin-2017-0166>
- Gonçalves, B., Marcelino, R., Torres-Ronda, L., Torrents, C., & Sampaio, J. (2016). Effects of emphasising opposition and cooperation on collective movement behaviour during football small-sided games. *Journal of Sports Sciences*, 34(14), 1346–1354. <https://doi.org/10.1080/02640414.2016.1143111>
- Gonçalves, B. V., Figueira, B. E., Maçãs, V., & Sampaio, J. (2014). Effect of player position on movement behaviour, physical and physiological performances during an 11-a-side football game. *Journal of Sports Sciences*, 32(2), 191–199. <https://doi.org/10.1080/02640414.2013.816761>
- Gore, C. (2000). *Physiological Tests for Elite Athletes*. Human Kinetics.
- Goto, H., Morris, J. G., & Nevill, M. E. (2015). Motion analysis of U11 to U16 elite English Premier League Academy players. *Journal of Sports Sciences*, 33(12), 1248–1258. <https://doi.org/10.1080/02640414.2014.999700>
- Gréhaigne, J. F., Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationships in collective actions in soccer. *Journal of Sports Sciences*, 15(2), 137–149. <https://doi.org/10.1080/026404197367416>
- Harbourne, R. T., & Stergiou, N. (2009). Movement variability and the use of nonlinear tools: Principles to guide physical therapist practice. *Physical Therapy*, 89(3), 267–282. <https://doi.org/10.2522/ptj.20080130>
- Hewitt, A., Greenham, G., & Norton, K. (2016). Game style in soccer: What is it and can we quantify it? *International Journal of Performance Analysis in Sport*, 16, 355. <https://doi.org/10.1080/24748668.2016.11868892>
- Hill-Haas, S., Rowsell, G., Coutts, A., & Dawson, B. (2008). The reproducibility of physiological responses and performance profiles of youth soccer players in small-sided games. *International Journal of Sports Physiology and Performance*, 3(3), 393–396. <https://doi.org/10.1123/ijspp.3.3.393>

- 611 Hodgson, C., Akenhead, R., & Thomas, K. (2014). Time-motion analysis of acceleration demands of 4v4 small-sided
612 soccer games played on different pitch sizes. *Human Movement Science*, 33, 25–32.
613 <https://doi.org/10.1016/j.humov.2013.12.002>
- 614 Hoppe, M. W., Baumgart, C., Polglaze, T., & Freiwald, J. (2018). Validity and reliability of GPS and LPS for
615 measuring distances covered and sprint mechanical properties in team sports. *PLOS ONE*, 13(2), e0192708.
616 <https://doi.org/10.1371/journal.pone.0192708>
- 617 Hristovski, R., Davids, Araujo, D., Passos, P., Torrents, C., Aceski, A., & Tufekcievski. (2013). *Creativity in sport*
618 *and dance: Ecological dynamics on a hierarchically soft-assembled perception-action landscape*. (pp. 259–271).
- 619 Jara, D., Ortega, E., Gómez-Ruano, M.-Á., Weigelt, M., Nikolic, B., & Sainz de Baranda, P. (2019). Physical and
620 Tactical Demands of the Goalkeeper in Football in Different Small-Sided Games. *Sensors*, 19(16), 3605.
621 <https://doi.org/10.3390/s19163605>
- 622 Laakso, T., Davids, K., Luhtanen, P., Liukkonen, J., & Travassos, B. (2022). How football team composition
623 constrains emergent individual and collective tactical behaviours: Effects of player roles in creating different
624 landscapes for shared affordances in small-sided and conditioned games. *International Journal of Sports Science*
625 *& Coaching*, 17(2), 346–354. <https://doi.org/10.1177/17479541211030076>
- 626 Lames, M., Erdmann, J., & Walter, F. (2010). Oscillations in football—Order and disorder in spatial interactions
627 between the two teams. *International Journal of Sport Psychology*, 41, 85–86.
- 628 Lee, K. A., Hicks, G., & Nino-Murcia, G. (1991). Validity and reliability of a scale to assess fatigue. *Psychiatry*
629 *Research*, 36(3), 291–298. [https://doi.org/10.1016/0165-1781\(91\)90027-m](https://doi.org/10.1016/0165-1781(91)90027-m)
- 630 Lefever, D. W. (1926). Measuring Geographic Concentration by Means of the Standard Deviational Ellipse. *American*
631 *Journal of Sociology*, 32(1), 88–94. <https://doi.org/10.1086/214027>
- 632 Leser, R., Baca, A., & Ogris, G. (2011). Local Positioning Systems in (Game) Sports. *Sensors*, 11(10), 9778–9797.
633 <https://doi.org/10.3390/s111009778>
- 634 Linke, D., Link, D., & Lames, M. (2018). Validation of electronic performance and tracking systems EPTS under
635 field conditions. *PLOS ONE*, 13(7), e0199519. <https://doi.org/10.1371/journal.pone.0199519>
- 636 Liu, H., Gómez, M.-A., Gonçalves, B., & Sampaio, J. (2016). Technical performance and match-to-match variation
637 in elite football teams. *Journal of Sports Sciences*, 34(6), 509–518.
638 <https://doi.org/10.1080/02640414.2015.1117121>
- 639 Los Arcos, A., Martínez-Santos, R., Yanci, J., Martín, J., & Castagna, C. (2014). Variability of objective and
640 subjective intensities during ball drills in youth soccer players. *Journal of Strength and Conditioning Research*,
641 28(3), 752–757. <https://doi.org/10.1519/JSC.0b013e3182a47f0b>
- 642 Low, B., Coutinho, D., Gonçalves, B., Rein, R., Memmert, D., & Sampaio, J. (2019). A systematic review of collective
643 tactical behaviours in football using positional data. *Sports Medicine*, 50, 1–43. <https://doi.org/10.1007/s40279-019-01194-7>
- 645 Machado, J. C., Góes, A., Aquino, R., Bedo, B. L. S., Viana, R., Rossato, M., Scaglia, A., & Ibáñez, S. J. (2022).
646 Applying Different Strategies of Task Constraint Manipulation in Small-Sided and Conditioned Games: How
647 Do They Impact Physical and Tactical Demands? *Sensors*, 22(12), 4435. <https://doi.org/10.3390/s22124435>
- 648 Machado, J., Barreira, D., Teoldo, I., Serra-Olivares, J., Góes, A., & José Scaglia, A. (2020). Tactical Behaviour of
649 Youth Soccer Players: Differences Depending on Task Constraint Modification, Age and Skill Level. *Journal of*
650 *Human Kinetics*, 75, 225–238. <https://doi.org/10.2478/hukin-2020-0051>
- 651 Mallo, J., Mena, E., Nevado, F., & Paredes, V. (2015). Physical Demands of Top-Class Soccer Friendly Matches in
652 Relation to a Playing Position Using Global Positioning System Technology. *Journal of Human Kinetics*, 47,
653 179–188. <https://doi.org/10.1515/hukin-2015-0073>
- 654 Malone, J. J., Jaspers, A., Helsen, W., Merks, B., Frencken, W. G. P., & Brink, M. S. (2018). Seasonal Training Load
655 and Wellness Monitoring in a Professional Soccer Goalkeeper. *International Journal of Sports Physiology and*
656 *Performance*, 13(5), 672–675. <https://doi.org/10.1123/ijsp.2017-0472>

- Marcelino, R., Sampaio, J., Amichay, G., Gonçalves, B., Couzin, I. D., & Nagy, M. (2020). Collective movement analysis reveals coordination tactics of team players in football matches. *Chaos, Solitons & Fractals*, 138, 109831. <https://doi.org/10.1016/j.chaos.2020.109831>
- McGarry, T., Anderson, D. I., Wallace, S. A., Hughes, M. D., & Franks, I. M. (2002). Sport competition as a dynamical self-organizing system. *Journal of Sports Sciences*, 20(10), 771–781. <https://doi.org/10.1080/026404102320675620>
- Memmert, D. (2021). *Match Analysis: How to Use Data in Professional Sport*. Routledge.
- Memmert, D., Lemmink, K. A. P. M., & Sampaio, J. (2017). Current approaches to tactical performance analyses in soccer using position data. *Sports Medicine*, 47(1), 1–10. <https://doi.org/10.1007/s40279-016-0562-5>
- Mendes, R. S., Malacarne, L. C., & Anteneodo, C. (2007). Statistics of football dynamics. *The European Physical Journal B*, 57(3), 357–363. <https://doi.org/10.1140/epjb/e2007-00177-4>
- Nieto, S., Castellano, J., Echeazarra, I., & Fernández, E. (2022). Effects on collective behaviour and locomotor and neuromuscular response in young players by varying the length of the pitch in 11-a-side football. *International Journal of Sports Science & Coaching*, 17479541221101604. <https://doi.org/10.1177/17479541221101603>
- O'Donoghue, P. (2009). *Research methods for sports performance analysis*. Routledge. <https://doi.org/10.4324/9780203878309>
- Ogris, G., Leser, R., Horsak, B., Kornfeind, P., Heller, M., & Baca, A. (2012). Accuracy of the LPM tracking system considering dynamic position changes. *Journal of Sports Sciences*, 30(14), 1503–1511. <https://doi.org/10.1080/02640414.2012.712712>
- Olthof, S. B. H., Frencken, W. G. P., & Lemmink, K. A. P. M. (2018). Match-derived relative pitch area changes the physical and team tactical performance of elite soccer players in small-sided soccer games. *Journal of Sports Sciences*, 36(14), 1557–1563. <https://doi.org/10.1080/02640414.2017.1403412>
- Ometto, L., Vasconcellos, F. V., Cunha, F. A., Teoldo, I., Souza, C. R. B., Dutra, M. B., O'Sullivan, M., & Davids, K. (2018). How manipulating task constraints in small-sided and conditioned games shapes emergence of individual and collective tactical behaviours in football: A systematic review. *International Journal of Sports Science & Coaching*, 13(6), 1200–1214. <https://doi.org/10.1177/1747954118769183>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ* 372, n71. doi: 10.1136/bmj.n71
- Palut, Y., & Zanone, P.-G. (2005). A dynamical analysis of tennis: Concepts and data. *Journal of Sports Sciences*, 23(10), 1021–1032. <https://doi.org/10.1080/02640410400021682>
- Paul, D. J., Bradley, P. S., & Nassis, G. P. (2015). Factors affecting match running performance of elite soccer players: Shedding some light on the complexity. *International Journal of Sports Physiology and Performance*, 10(4), 516–519. <https://doi.org/10.1123/IJSP.2015-0029>
- Pincus, S. M. (1991). Approximate entropy as a measure of system complexity. *Proceedings of the National Academy of Sciences*, 88(6), 2297–2301. <https://doi.org/10.1073/pnas.88.6.2297>
- Pol, R., Balagué, N., Ric, A., Torrents, C., Kiely, J., & Hristovski, R. (2020). Training or synergizing? Complex systems principles change the understanding of sport processes. *Sports Medicine - Open*, 6(1), 28. <https://doi.org/10.1186/s40798-020-00256-9>
- Portas, M. D., Harley, J. A., Barnes, C. A., & Rush, C. J. (2010). The validity and reliability of 1-Hz and 5-Hz global positioning systems for linear, multidirectional, and soccer-specific activities. *International Journal of Sports Physiology and Performance*, 5(4), 448–458. <https://doi.org/10.1123/ijsp.5.4.448>
- Praça, G. M., Andrade, A. G. P., Bredt, S. da G. T., Moura, F. A., & Moreira, P. E. D. (2020). Progression to the target vs. Regular rules in Soccer small-sided Games. *Science and Medicine in Football*, 0(0), 1–6. <https://doi.org/10.1080/24733938.2020.1869811>
- Praça, G. M., Folgado, H., Andrade, A. G. P. de, & Greco, P. J. (2016). Influence of additional players on collective tactical behavior in small-sided soccer games. *Revista Brasileira de Cineantropometria & Desempenho Humano*, 18, 62–71. <https://doi.org/10.5007/1980-0037.2016v18n1p62>

- 705 Praça, G. M., Moreira, P. E. D., Dieguez, G. T. de O., Barbosa, T. de O., Brandão, L. H. A., & Custódio, I. J. de O.
706 (2021). The impact of match venue on performance indicators and tactical behaviour in youth soccer players.
707 *International Journal of Performance Analysis in Sport*, 0(0), 1–11.
708 <https://doi.org/10.1080/24748668.2021.1952831>
- 709 Praça, G., Moreira, P., Andrade, A., Clemente, F., Oliveira, W., & Demetrio Cunha, G. (2022). Integrating notational
710 and positional analysis to investigate tactical behavior in offensive and defensive phases of football matches.
711 *Proceedings of the Institution of Mechanical Engineers Part P Journal of Sports Engineering and Technology*,
712 17543371221122044. <https://doi.org/10.1177/17543371221122044>
- 713 Preatoni, E., Ferrario, M., Donà, G., Hamill,
714 J., & Rodano, R. (2010). Motor variability in sports: A non-linear analysis of race walking. *Journal of Sports
715 Sciences*, 28(12), 1327–1336. <https://doi.org/10.1080/02640414.2010.507250>
- 716 Preciado, M., Anguera, M. T., Olarte, M., & Lapresa, D. (2019). Observational Studies in Male Elite Football: A
717 Systematic Mixed Study Review. *Frontiers in Psychology*, 10. <https://doi.org/10.3389/fpsyg.2019.02077>
- 718 Rago, V., Brito, J., Figueiredo, P., Costa, J., Barreira, D., Krstrup, P., & Rebelo, A. (2020). Methods to collect and
719 interpret external training load using microtechnology incorporating GPS in professional football: A systematic
720 review. *Research in Sports Medicine*, 28(3), 437–458. <https://doi.org/10.1080/15438627.2019.1686703>
- 721 Rampinini, E., Impellizzeri, F. M., Castagna, C., Coutts, A. J., & Wisløff, U. (2009). Technical performance during
722 soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *Journal of Science and
723 Medicine in Sport*, 12(1), 227–233. <https://doi.org/10.1016/j.jsams.2007.10.002>
- 724 Ranjitha, M., Nathan, K., & Joseph, L. (2020). Artificial Intelligence Algorithms and Techniques in the computation
725 of Player-Adaptive Games. *Journal of Physics: Conference Series*, 1427(1), 012006.
<https://doi.org/10.1088/1742-6596/1427/1/012006>
- 726 Rein, R., & Memmert, D. (2016). Big data and tactical analysis in elite soccer: Future challenges and opportunities
727 for sports science. *SpringerPlus*, 5(1), 1410. <https://doi.org/10.1186/s40064-016-3108-2>
- 728 Reis, M. A. M. D., & Almeida, M. B. (2020). The role of somatic maturation in the tactical effectiveness, efficiency
729 and variability of young soccer players. *International Journal of Performance Analysis in Sport*, 20(2), 305–321.
730 <https://doi.org/10.1080/24748668.2020.1743165>
- 731 Ric, A., Hristovski, R., Gonçalves, B., Torres, L., Sampaio, J., & Torrents, C. (2016). Timescales for exploratory
732 tactical behaviour in football small-sided games. *Journal of Sports Sciences*, 34(18), 1723–1730.
733 <https://doi.org/10.1080/02640414.2015.1136068>
- 734 Ric, A., Torrents, C., Gonçalves, B., Sampaio, J., & Hristovski, R. (2016). Soft-assembled Multilevel Dynamics of
735 Tactical Behaviors in Soccer. *Frontiers in Psychology*, 0. <https://doi.org/10.3389/fpsyg.2016.01513>
- 736 Ric, A., Torrents, C., Gonçalves, B., Torres-Ronda, L., Sampaio, J., & Hristovski, R. (2017). Dynamics of tactical
737 behaviour in association football when manipulating players' space of interaction. *PLOS ONE*, 12(7), e0180773.
738 <https://doi.org/10.1371/journal.pone.0180773>
- 739 Richman, J. S., & Moorman, J. R. (2000). Physiological time-series analysis using approximate entropy and sample
740 entropy. *American Journal of Physiology-Heart and Circulatory Physiology*, 278(6), H2039–H2049.
741 <https://doi.org/10.1152/ajpheart.2000.278.6.H2039>
- 742 Rico-González, M., Los Arcos, A., Nakamura, F. Y., Gantois, P., & Pino-Ortega, J. (2020). A comparison between
743 UWB and GPS devices in the measurement of external load and collective tactical behaviour variables during a
744 professional official match. *International Journal of Performance Analysis in Sport*, 20(6), 994–1002.
745 <https://doi.org/10.1080/24748668.2020.1823153>
- 746 Rico-González, M., Pino-Ortega, J., Castellano, J., Oliva-Lozano, J. M., & Arcos, A. L. (2021). Reference values for
747 collective tactical behaviours based on positional data in professional football matches: A systematic review.
748 *Biology of Sport*, 39(1), 101–114. <https://doi.org/10.5114/biolSport.2021.102921>
- 749 Rojas-Valverde, D., Gómez-Carmona, C. D., Gutiérrez-Vargas, R., & Pino-Ortega, J. (2019). From big data mining
750 to technical sport reports: The case of inertial measurement units. *BMJ Open Sport & Exercise Medicine*, 5(1),
751 e000565. <https://doi.org/10.1136/bmjsem-2019-000565>

- Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Love, T. D., Bracken, R. M., & Kilduff, L. P. (2016). Changes in Acceleration and Deceleration Capacity Throughout Professional Soccer Match-Play. *The Journal of Strength & Conditioning Research*, 30(10), 2839–2844. <https://doi.org/10.1519/JSC.0000000000000805>
- Sampaio, J. E., Lago, C., Gonçalves, B., Maças, V. M., & Leite, N. (2014). Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *Journal of Science and Medicine in Sport*, 17(2), 229–233. <https://doi.org/10.1016/j.jsams.2013.04.005>
- Sampaio, J., & Vitor, M. (2012). Measuring Tactical Behaviour in Football. *International Journal of Sports Medicine*, 33, 395–401. <https://doi.org/10.1055/s-0031-1301320>
- Santos, S., Coutinho, D., Gonçalves, B., Schöllhorn, W., Sampaio, J., & Leite, N. (2018). Differential Learning as a Key Training Approach to Improve Creative and Tactical Behavior in Soccer. *Research Quarterly for Exercise and Sport*, 89, 1–14. <https://doi.org/10.1080/02701367.2017.1412063>
- Sarmiento, H., Clemente, F. M., Araújo, D., Davids, K., McRobert, A., & Figueiredo, A. (2018). What Performance Analysts Need to Know About Research Trends in Association Football (2012–2016): A Systematic Review. *Sports Medicine*, 48(4), 799–836. <https://doi.org/10.1007/s40279-017-0836-6>
- Saxton, M. J. (1996). Anomalous diffusion due to binding: A Monte Carlo study. *Biophysical Journal*, 70(3), 1250–1262. [https://doi.org/10.1016/S0006-3495\(96\)79682-0](https://doi.org/10.1016/S0006-3495(96)79682-0)
- Seifert, L., Button, C., & Davids, K. (2013). Key properties of expert movement systems in sport: An ecological dynamics perspective. *Sports Medicine (Auckland, N.Z.)*, 43(3), 167–178. <https://doi.org/10.1007/s40279-012-0011-z>
- Silva, P., Chung, D., Carvalho, T., Cardoso, T., Davids, K., Araújo, D., & Garganta, J. (2016). Practice effects on intra-team synergies in football teams. *Human Movement Science*, 46, 39–51. <https://doi.org/10.1016/j.humov.2015.11.017>
- Silva, P., Duarte, R., Esteves, P., Travassos, B., & Vilar, L. (2016). Application of entropy measures to analysis of performance in team sports. *International Journal of Performance Analysis in Sport*, 16(2), 753–768. <https://doi.org/10.1080/24748668.2016.11868921>
- Silva, P., Vilar, L., Davids, K., Araújo, D., & Garganta, J. (2016). Sports teams as complex adaptive systems: Manipulating player numbers shapes behaviours during football small-sided games. *SpringerPlus*, 5(1), 191. <https://doi.org/10.1186/s40064-016-1813-5>
- Stagno, K. M., Thatcher, R., & van Someren, K. A. (2007). A modified TRIMP to quantify the in-season training load of team sport players. *Journal of Sports Sciences*, 25(6), 629–634. <https://doi.org/10.1080/02640410600811817>
- Stergiou, N., Buzzi, U., Kurz, M., & Heidel, J. (2004). *Nonlinear tools in human movement*. Champaign, IL , Human Kinetics.
- Teixeira, J. E., Alves, A. R., Ferraz, R., Forte, P., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M. (2022). Effects of chronological age, relative age, and maturation status on accumulated training load and perceived exertion in young sub-elite football players. *Frontiers in Physiology*, 13, 832202.
- Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M. (2021a). Monitoring accumulated training and match load in football: A systematic review. *International Journal of Environmental Research and Public Health*, 18(8), 3906. <https://doi.org/10.3390/ijerph18083906>
- Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M. (2021b). Quantifying sub-elite youth football weekly training load and recovery variation. *Applied Sciences*, 11(11), 4871. <https://doi.org/10.3390/app11114871>
- Teixeira, J. E., Leal, M., Ferraz, R., Ribeiro, J., Cachada, J. M., Barbosa, T. M., Monteiro, A. M., & Forte, P. (2021). Effects of match location, quality of opposition and match outcome on match running performance in a Portuguese professional football team. *Entropy*, 23(8), 973. <https://doi.org/10.3390/e23080973>
- Teixeira, J., Forte, P., Ferraz, R., Branquinho, L., Silva, A., Barbosa, T., & Monteiro, A. (2022). *Methodological Procedures for Non-Linear Analyses of Physiological and Behavioural Data in Football*. <https://doi.org/10.5772/intechopen.102577>

- 799 Travassos, B., Araújo, D., Vilar, L., & McGarry, T. (2011). Interpersonal coordination and ball dynamics in futsal
800 (indoor football). *Human Movement Science*, 30(6), 1245–1259. <https://doi.org/10.1016/j.humov.2011.04.003>
- 801 Travassos, B., Davids, Araujo, D., & Esteves, P. (2013). Performance analysis in team sports: Advances from an
802 ecological dynamics approach. *International Journal of Performance Analysis in Sport*, 13, 89–95.
803 <https://doi.org/10.1080/24748668.2013.11868633>
- 804 Travassos, B., Gonçalves, B., Marcelino, R., Monteiro, R., & Sampaio, J. (2014). How perceiving additional targets
805 modifies teams' tactical behavior during football small-sided games. *Human Movement Science*, 38, 241–250.
806 <https://doi.org/10.1016/j.humov.2014.10.005>
- 807 Vidal-Codina, F., Evans, N., Fakir, B. E., & Billingham, J. (2022). *Automatic event detection in football using tracking*
808 *data* (arXiv:2202.00804). arXiv. <https://doi.org/10.48550/arXiv.2202.00804>
- 809 Vilar, L., Araújo, D., Davids, K., Travassos, B., Duarte, R., & Parreira, J. (2014). Interpersonal coordination
810 tendencies supporting the creation/prevention of goal scoring opportunities in futsal. *European Journal of Sport*
811 *Science*, 14(1), 28–35. <https://doi.org/10.1080/17461391.2012.725103>
- 812 Welsh, A. H., & Knight, E. J. (2015). “Magnitude-based Inference”: A Statistical Review. *Medicine and Science in*
813 *Sports and Exercise*, 47(4), 874–884. <https://doi.org/10.1249/MSS.0000000000000451>
- 814 Wisbey, B., Montgomery, P. G., Pyne, D. B., & Rattray, B. (2010). Quantifying movement demands of AFL football
815 using GPS tracking. *Journal of Science and Medicine in Sport*, 13(5), 531–536.
816 <https://doi.org/10.1016/j.jsams.2009.09.002>
- 817 Yentes, J. M., Hunt, N., Schmid, K. K., Kaipust, J. P., McGrath, D., & Stergiou, N. (2013). The appropriate use of
818 approximate entropy and sample entropy with short data sets. *Annals of Biomedical Engineering*, 41(2), 349–
819 365. <https://doi.org/10.1007/s10439-012-0668-3>
- 820 Yuill, R. S. (1971). The Standard Deviational Ellipse; An Updated Tool for Spatial Description. *Geografiska Annaler:*
821 *Series B, Human Geography*, 53(1), 28–39. <https://doi.org/10.1080/04353684.1971.11879353>

Table 1(on next page)

Search terms and following keywords in the screening procedures of systematic review.

Search terms and following keywords in the screening procedures of systematic review.

1 **Table 1** – Search terms and following keywords in the screening procedures of systematic review.

Search Term		Keywords
Population	1	“soccer” OR “football” OR “Association football”
Intervention	2	“integrated” OR “integration” OR “comparison” OR “integration”
Comparison/ Outcomes	3	<p>Physiological set: “training load” OR “external training load” OR “internal training load” OR “physical performance” OR “physiological performance” OR “physical response” OR “physical demands” OR “physiological response” OR “physiological demands” OR “activity profile” OR “time-motion” OR “workload” OR “work-rate” OR “loading” OR “match running performance” OR “match load” OR “match demands” OR “weekly load” OR “heart rate” OR “TRIMP” OR “perceived exertion” OR “distances” OR “sprint” OR “acceleration” OR “deceleration” OR “metabolic power” OR “energy cost” OR “high intensity” OR “running” OR “conditioning” OR “fitness” OR “biomechanics” OR “kinetic” OR “kinematic” OR “physiology”</p> <p>Positional data: “positional” OR “positioning” OR “behavioral data” OR “behaviour data” OR “tactical behavior” OR “tactical behaviour” OR “collective behavior” OR “collective behaviour” OR “team behavior” OR “team behavior” OR “movement behavior” OR “movement behaviour” OR “patterns” OR “constraints” OR “interpersonal coordination” OR “inter-personal coordination” OR “intra-team dyads” OR “inter-team dyads” OR “synchronization” OR “synergy” OR “tactical adjustments” OR “game dynamics” OR “dynamic” OR “variability” OR “stability” OR “regularity” OR “predictability” OR “spatial-temporal” OR “spatio-temporal” OR “complex systems” OR “dynamical systems” OR “complexity” OR “self-organization” OR “self-similarity” OR “self-organization” OR “chaos”</p>
Boolean phrase	4	((#4) AND #3) AND #2) AND #1

2

3

Table 2(on next page)

Summary of the sampling characteristics in the studies included for systematic review and its quality score.

Summary of the sampling characteristics in the studies included for systematic review and its quality score.

1 **Table 2** – Summary of the sampling characteristics in the studies included for systematic review and its quality score.

Reference (year)	Study design	Population, Competitive Level	Sample (N)	Sex	Age (y)	Expertise level (y)
Baptista et al. (2020)	RCT	Adult, Semiprofessional	23	Male	24.9 ± 6.5	12.6 ± 5.5
Canton et al. (2021)	RCT	Youth, High-Level	24	Male	U12: 11.3 ± 0.8	U12: 3.13 ± 1.5
Coutinho et al. (2017)	RCT	Youth, Amateur	12	Male	15.9 ± 0.8	8.9 ± 2.4
Coutinho et al. (2019)	RCT	Youth, Amateur	12	Male	15.9 ± 0.8	8.9 ± 2.4
Coutinho, et al. (2019)	RCT	Youth, ND	40	Male	U13 (n=20): 11.3 ± 0.8 U15 (n=20): 13.3 ± 0.6	U13 (n=20): 4.9 ± 2.7 U15 (n=20): 7.0 ± 1.6
Coutinho et al. (2020)	RCT	Youth, ND	10	Male	13.7 ± 0.5	6.1 ± 0.9
Coutinho et al. (2022)	RCT	Youth, ND	114	Male	U9: 7.9 ± 0.9 U11: 9.5 ± 0.9 U13: 11.6 ± 0.8 U15: 13.9 ± 0.6 U17: 16.2 ± 0.7 U19: 17.9 ± 0.4	U9: 2.7 ± 1.1 U11: 3.9 ± 1.2 U13: 4.9 ± 2.0 U15: 6.8 ± 2.5 U17: 7.9 ± 2.8 U19: 9.5 ± 2.1
Coutinho et al. (2022)	RCT	Youth, Regional Level	20	Male	16.1 ± 0.9	7.5 ± 3.4
Coutinho et al. (2022)	RCT	Youth, ND	21	Male	16.2 ± 0.6	8.3 ± 2.8
Ferraz et al. (2020)	RCT	Adult, Professional	20	Male	22.3 ± 2.1	10.3 ± 3.4
Figueira et al. (2018)	RCT	Youth, Elite	22	Male	U15 (n=22): 13.6 ± 0.4 U17 (n=22): 15.3 ± 0.4	U15 (n=22): 5.1 ± 1.3 U17 (n=22): 7.2 ± 1.4
Folgado et al. (2015)	Observational cohort	Adult, Professional	23	Male	25.5 ± 3.6	9.0 ± 3.7
Folgado et al. (2018)	Observational cohort	Adult, Professional	30	Male	23.7 ± 4.2	4.8 ± 4.2
Folgado et al. (2019)	RCT	Youth, National Level	20	Male	U15: 14.1 ± 0.5	U15: 6.4 ± 1.8
Gonçalves et al. (2014)	Observational cohort	Youth, Elite	22	Male	18.1 ± 0.7	9.4 ± 1.3
Gonçalves et al. (2017)	RCT	Adult, Professional	19	Male	25.1 ± 4.1	18.8 ± 5.3
Gonçalves et al. (2018)	Observational cohort	Adult, Professional	28	Male	24.7 ± 4.7	6.5 ± 4.7
Jara et al. (2019)	RCT	Adult, Elite	3	Male	24.7 ± 7.2	11.0 ± 4.7
Machado et al. (2022)	RCT	Youth, Recreational	10	Male	16.89 ± 0.11	ND
Nieto et al. (2022)	RCT	Youth, Elite	22	Male	14.6 ± 0.3	5.5 ± 0.5
Olthof et al. (2018)	Observational cohort	Youth, Professional	148	Male	U13 (n=36): 12.5 ± 0.5 U15 (n=43): 14.4 ± 0.5 U17 (n=28): 16.6 ± 3.2 U19 (n=43): 17.9 ± 1.0	ND
Praça et al. (2016)	Observational cohort	Youth, National Level	18	Male	16.4 ± 0.7	4.2 ± 0.0
Praça et al. (2021)	Observational cohort	Youth, National Level	50	Male	U17 (n=25): 16.79 ± 0.61 U20 (n=25): 19.08 ± 0.61	ND
Ric et al. (2016)	RCT	Adult, Professional	8	Male	26 ± 4.96	19.6 ± 4.9
Ric et al. (2017)	RCT	Adult, Professional	21	Male	25.1 ± 4.1	18.8 ± 5.3
Sampaio et al. (2014)	Observational cohort	Adult, volunteer	24	Male	20.8 ± 1.0	5.2 ± 1.3
All studies	-	-	764	-	16.81 ± 1.63	4.2 ± 3.83

Abbreviations: ND – Not described; U – Under; QS – Quality Score; RCT – randomized controlled trial; y – years.

Table 3(on next page)

Modified Downs and Black scale for reviewed intervention studies.

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Table 3 – Modified Downs and Black scale for reviewed intervention studies.

Reference (year)	Item 1	Item 2	Item 3	Item 6	Item 7	Item 10	Item 12	Item 15	Item 16	Item 18	Item 20	Item 22	Item 23	Item 25	Total score (out of 14)
Folgado et al. (2015)	1	1	1	1	0	1	1	0	1	0	1	1	0	0	9
Folgado et al. (2018)	1	1	1	0	1	1	1	0	0	1	1	1	1	0	10
Gonçalves et al. (2014)	1	1	1	1	0	1	1	1	1	0	0	0	0	1	8
Gonçalves et al. (2018)	1	1	1	1	1	0	1	0	1	1	1	0	1	1	11
Olthof et al. (2018)	1	1	1	1	0	1	1	1	1	0	0	1	0	1	10
Praça et al. (2016)	1	1	1	1	0	1	1	0	1	1	0	0	1	0	9
Praça et al. (2021)	1	1	1	1	1	1	1	1	1	0	0	1	0	1	11
Sampaio et al. (2014)	1	1	0	1	1	0	1	0	1	1	0	0	1	0	8

Notes: 0 = no; 1 = yes; U = unable to determine. Item 1: clear aim/hypothesis; Item 2: outcome measures clearly described; Item 3: patient characteristics clearly described; Item 6: main findings clearly described; Item 7: measures of random variability provided; Item 10: actual probability values reported; Item 12: participants prepared to participate representative of entire population; Item 15: blinding of outcome measures; Item 16: analysis completed was planned; Item 18: appropriate statistics; Item 20: valid and reliable outcome measures; Item 22: participants recruited over same period; Item 23: randomised; Item 25: adjustment made for confounding variables.

Table 4(on next page)

Physiotherapy evidence database scale (PEDro) for reviewed intervention groups.

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Table 4 – Physiotherapy evidence database scale (PEDro) for reviewed intervention groups.

Reference (year)	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total score (out of 11)
Baptista et al. (2020)	1	1	1	1	1	1	1	0	1	1	0	9
Canton et al. (2021)	1	1	1	1	1	0	1	1	1	0	0	8
Coutinho et al. (2017)	1	1	1	1	1	1	1	1	1	0	0	9
Coutinho et al. (2019)	1	1	1	1	1	1	1	0	1	1	0	9
Coutinho, et al. (2019)	0	1	1	1	1	0	0	1	1	0	0	6
Coutinho et al. (2020)	1	1	1	0	1	0	1	1	1	0	1	8
Coutinho et al. (2022)	1	1	1	1	1	1	1	0	1	1	0	9
Coutinho et al. (2022)	0	1	1	1	1	1	1	0	1	0	1	8
Coutinho et al. (2022)	1	1	1	1	1	1	1	0	1	0	1	9
Ferraz et al. (2020)	1	1	0	1	1	1	1	1	1	0	0	8
Figueira et al. (2018)	1	1	1	1	1	1	1	1	1	0	0	9
Folgado et al. (2019)	1	1	1	1	1	1	1	1	1	0	0	9
Gonçalves et al. (2017)	1	1	1	1	1	0	1	0	1	0	0	7
Jara et al. (2019)	1	1	1	1	0	1	1	1	1	0	0	8
Machado et al. (2022)	1	1	1	1	1	1	1	0	1	0	0	8
Nieto et al. (2022)	1	1	1	1	0	1	1	0	0	1	0	7
Ric et al. (2016)	1	1	1	1	1	1	1	0	1	1	0	9
Ric et al. (2017)	1	1	1	1	1	0	1	0	1	0	0	7

Notes: 0 = item was not satisfied; 1 = item was satisfied. Item 1: eligibility criteria were specified; Item 2: subjects were randomly allocated to groups; Item 3: allocation was concealed; Item 4: the groups were similar at baseline regarding the most important prognostic indicators; Item 5: there was blinding of all subjects; Item 6: there was blinding of all therapists who administered the therapy; Item 7: there was blinding of all assessors who measured at least one key outcome; Item 8: measurements of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; Item 9: all subjects for whom outcome measurements were available received the treatment or control condition as allocated, or where this was not the case, data for at least one key outcome were analysed by “intention to treat”; Item 10: the results of between groups statistical comparisons are reported for at least one key outcome; Item 11: the study provides both point measurements and measurements of variability for at least one key outcome.

Table 5(on next page)

Summary of performance dimensions, measures, measurements and their thresholds/metric formulas in the included articles.

Summary of performance dimensions, measures, measurements and their thresholds/metric formulas in the included articles.

Table 5 – Summary of performance dimensions, measures, measurements and their thresholds/metric formulas in the included articles.

Dimension	Measure	Measurement	Description, thresholds and/or metric formula	Reference	Further reading
Physical data	External load	TD (m)	Higher Ratio ($> 16 \text{ km} \cdot \text{h}^{-1}$), Moderate Ratio ($10.0\text{--}15.9 \text{ km} \cdot \text{h}^{-1}$), Lower Ratio: $7.0\text{--}9.9 \text{ km} \cdot \text{h}^{-1}$ with distance covered at very low intensities ($0.0\text{--}6.9 \text{ km} \cdot \text{h}^{-1}$)	(Canton et al., 2021; Coutinho et al., 2019; Coutinho et al., 2019)	(Abade et al., 2014; Bradley & Ade, 2018; Hodgson et al., 2014)
			Walking ($0.0\text{--}3.5 \text{ km} \cdot \text{h}^{-1}$), Jogging ($3.6\text{--}14.3 \text{ km} \cdot \text{h}^{-1}$), Running ($14.4\text{--}19.7 \text{ km} \cdot \text{h}^{-1}$), and Sprinting ($>19.8 \text{ km} \cdot \text{h}^{-1}$).	(Coutts & Duffield, 2010; Ferraz et al., 2020; Figueira et al., 2018; Folgado et al., 2015, 2018; Gonçalves et al., 2017; Gonçalves et al., 2018; Ric et al., 2016; Ric et al., 2017)	(Duarte et al., 2013; Folgado et al., 2014; Giménez et al., 2018; Gonçalves et al., 2017)
			Zone 1 ($0\text{--}6.9 \text{ km} \cdot \text{h}^{-1}$), zone 2 ($7\text{--}9.9 \text{ km} \cdot \text{h}^{-1}$), zone 3 ($10\text{--}12.9 \text{ km} \cdot \text{h}^{-1}$), zone 4 ($13\text{--}15.9 \text{ km} \cdot \text{h}^{-1}$), zone 5 ($16\text{--}17.9 \text{ km} \cdot \text{h}^{-1}$) and zone 6 ($\geq 18 \text{ km} \cdot \text{h}^{-1}$).	(Sampaio et al., 2014)	(Hill-Haas et al., 2008)
		High Speed ($\text{km} \cdot \text{h}^{-1}$)	Distance covered in the high ratio/distance covered in walking multiplied by 100.	(Coutinho et al., 2019; Coutinho et al., 2019)	(Abade et al., 2014; Gonçalves et al., 2018)
			Distance covered at high intensity ($\geq 19.8 \text{ km} \cdot \text{h}^{-1}$) and number of sprints (frequency of displacements $\geq 25.2 \text{ km} \cdot \text{h}^{-1}$)	(Olthof et al., 2018)	(Abt & Lovell, 2009; Goto et al., 2015)
			Distance covered at three speed zones ($14.40\text{--}19.79 \text{ km} \cdot \text{h}^{-1}$, $19.80\text{--}22.99 \text{ km} \cdot \text{h}^{-1}$, higher than $23.00 \text{ km} \cdot \text{h}^{-1}$) and number of sprints (frequency of displacements $\geq 23.00 \text{ km} \cdot \text{h}^{-1}$)	(Praça et al., 2021)	(Mallo et al., 2015; Praça et al., 2020)
		Game Pace or Average Speed ($\text{km} \cdot \text{h}^{-1}$ or CV)	Players' average speed displacement, expressed as meters or CV.	(Canton et al., 2021; Coutinho et al., 2019; Coutinho et al., 2019)	(Ferraz et al., 2017, 2018; Gonçalves et al., 2019)
		ACC/DEC ($\text{m} \cdot \text{s}^{-2}$)	ACC: $0.5\text{--}3.0 \text{ m} \cdot \text{s}^{-2}$; DEC: $> -3.0 \text{ m} \cdot \text{s}^{-2}$	(Coutinho et al., 2017)	(Dalen et al., 2016; Russell et al., 2016)
		Body load	$\frac{\sqrt{(a_{y1} - a_{y-1})^2 + a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}}{100}$	(Gonçalves et al., 2017)	(Buchheit et al., 2014)
		CV	Magnitude of the variability in the distance between players', expressed by the coefficient of variation CV (%)	(Coutinho et al., 2019; Coutinho et al., 2020; Figueira et al., 2018; Gonçalves et al., 2017)	(Frencken et al., 2012; Harbourne & Stergiou, 2009; Seifert et al., 2013; Travassos et al., 2014)
Positional data	Spatial and temporal features	ApEn	Ranged 0 to 2, in which lower values correspond to more repeatable patterns). The imputed values used to compute were 2 to vector length (m) and $0.2 \cdot \text{std}$ to the tolerance (r).	(Baptista et al., 2020; Coutinho et al., 2020; Coutinho et al., 2019; Ferraz et al., 2020; Figueira et al., 2018; Gonçalves et al., 2017; Sampaio et al., 2014)	(Duarte et al., 2012; Gonçalves et al., 2016; Gréhaigne et al., 1997; Pincus, 1991; Preatoni et al., 2010; Richman & Moorman, 2000; Seifert et al., 2013; Silva, Duarte, et al., 2016; Stergiou et al., 2004; Yentes et al., 2013)
		Boltzmann–Gibbs–Shannon entropy	Probabilities of configurations were calculated as limit (large N) relative frequencies for stationary distributions: $pi - ni/N$ where ni and N is the frequency and number of the configuration respectively.	(Ric et al., 2016)	(Balescu, 1975)
		MSE SamEn	SampEn and MSE curves to a range of different timescales, calculating the area under and complexity index.	(Canton et al., 2021)	(Busa & van Emmerik, 2016; M. Costa et al., 2005)
		SEI	Width and length displacements from each positioning time series to the mean position.	(Canton et al., 2021; Figueira et al., 2018; Gonçalves et al., 2017; Praça et al., 2021)	(Arede et al., 2021; Clemente et al., 2018; Clemente et al., 2018; Travassos et al., 2014)
		Stretch Index (meters or ApEn)	Men of the distances between each player and the geometric centre of the team.	(Coutinho et al., 2019; Olthof et al., 2018; Praça et al., 2021)	(Bourbousson et al., 2010; Clemente et al., 2013; Clemente et al., 2018; Duarte et al., 2013; Lames et al., 2010; Travassos et al., 2014)
	Complex Index	Dynamic overlap $\langle \text{qd}(t) \rangle$	Average cosine auto-similarity of the overlap between configurations with increasing time lag $\langle q_d(t) \rangle = (1 - q_{stat})t^\alpha + q_{stat}$	(Ric et al., 2016)	(Hristovski et al., 2013; Saxton, 1996)
		Trapping strength	Probability of remaining inside the same attractor that is a conditional probability of a configuration being subsequently repeated (i.e., trapping strength and behavioural flexibility).		

Other dimensions (non-positional data)			Voronoi algorithms	Voronoi algorithms allow to compute a diagram represented by spatial cells for individual positional area (m ²).	(Baptista et al., 2020)	(Fonseca et al., 2012)
			Relative phase (Hilbert transform)	Longitudinal and lateral directions using near-in-phase synchronization of each dyad that was quantified by the percentage of time spent between −30° to 30° bin.	(Coutinho et al., 2020; Coutinho et al., 2019; Fernandes et al., 2010; Figueira et al., 2018; Folgado et al., 2015, 2019; Gonçalves et al., 2018; Gonçalves et al., 2017)	(Duarte et al., 2012; Duarte et al., 2012; Duarte et al., 2013; Folgado et al., 2014; Gonçalves et al., 2019; McGarry et al., 2002; Palut & Zanone, 2005; Sampaio & Vitor, 2012; Silva et al., 2016; Travassos et al., 2011a, 2011b, 2013)
			Speed synchronisation	0.0–3.5 km·h ^{−1} (low intensity); 3.6–14.3 km·h ^{−1} (moderate intensity); 14.4–19.7 km·h ^{−1} (high intensity); and >19.8 km·h ^{−1} (very high intensity).	(Folgado et al., 2018; Gonçalves et al., 2018)	(Folgado et al., 2014)
			Distance Player–Teammate	Interpersonal distance between each pair of players, both with teammates and opponents:		
			Distance Player–Opponent	$D(a_{x(t)y(t)}, b_{x(t)y(t)}) = \sqrt{(a_{x(t)y(t)})^2 + (a_{x(t)y(t)})^2}$ Where D is the distance, a is the player, x and y are the coordinates, and t is the time, and b is the teammate or opponent.	(Ferraz et al., 2020; Olthof et al., 2018; Ric et al., 2017; Sampaio et al., 2014)	(Gonçalves et al., 2014; Low et al., 2020; Silva et al., 2016)
			Distance from the target	Distance from the target according to ten categories: >37.45 m; 32.1 ± 37.45 m; 36.75 ± 32.1 m; 21.4 ± 26.75 m; 16.05 ± 21.4 m; 10.7 ± 16.05 m; 5.35 ± 10.7 m; 0 ± 5.35 m.	(Ric et al., 2017)	(Duarte, Araújo, Davids, et al., 2012)
			Total surface area or team effective playing space (m ²)	Smallest convex hull, that is the smallest polygonal area that it is delimited by the peripheral players	(Coutinho et al., 2017; Folgado et al., 2019; Olthof et al., 2018)	(Duarte et al., 2013; Folgado et al., 2014; Mendes et al., 2007; Ric, Torrents, et al., 2016; Russell et al., 2016; Sampaio & Vitor, 2012)
			Ellipses: SEA and PEA areas	Spatial analysis for a set of points in a two-dimensional space, which boundaries will enclose about the $100(1 - \alpha): \bar{x} = \frac{1}{n} \sum_{i=0}^n x_i, \bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$	(Jara et al., 2019)	(Batshchelet, 1981; Lefever, 1926; Yuill, 1971)
			Team's width and length			
			Team's speed contraction dispersion	Longitudinal position of team geometrical center (x axis) and lateral position of team geometrical center (y axis), expressed as meters, CV and length-per-width (LPW) ratio per team.	(Baptista et al., 2020; Canton et al., 2021; Coutinho et al., 2017; Gonçalves et al., 2017; Praça et al., 2021)	(Duarte et al., 2013; Folgado et al., 2014; Frencken et al., 2011; Mendes et al., 2007; Ric et al., 2016)
			Team centroid			
	Technical variables	Individual actions	Passes, dribbles and shots	Successful Passes (%), Successful Dribbles (%), Shots on Target (%), Goals (%)	(Coutinho et al., 2020)	(Liu et al., 2016; O'Donoghue, 2009; Santos et al., 2018)
				Distance covered at different intensities when dribbling; number of completed passes; completed passes distance; shots distance to the goal; distance between attacker and defender when shooting	(Folgado et al., 2019; Olthof et al., 2018)	(Rampinini et al., 2009)
				Successful pass reception and turnovers, goals scored and relative frequencies of players' passing interactions.		
				Transition probabilities were calculated dividing the number of each player's passes to his teammates, turnovers and goals by the total number of player interactions.	(Ric et al., 2017)	(Costa et al., 2005)
	Tactical variables	Ball Possession	Offensive/Defensive Phases	Duration of possession, team width, team length and their ratio (LPWR), as well as their coefficient of variation	(Canton et al., 2021; Olthof et al., 2018; Ric, Hristovski, et al., 2016)	(Collet, 2013; Costa et al., 2011; Gabin et al., 2012)
		Network	Dyad Nodes	Relative phase analysis was also divided according to each dyad average speed in three levels: for the whole team; for dyads with similar synchronisation tendencies; and for each dyad.	(Folgado et al., 2015; Ric et al., 2017)	(McGarry et al., 2002; Travassos et al., 2011a, 2013)
		Tactical actions	Patterns/Categories	Tactical actions classified as: penetration, offensive coverage, depth mobility, width and length, offensive unity, delay, defensive coverage, balance, concentration, defensive unity.	(Ric et al., 2017)	(M. Costa et al., 2005)
	Psychophysiological variables	Perceived Exertion	RPE (a.u.)	CR10-scale (0 to 10 arbitrary units).	(Coutinho et al., 2017)	(Lee et al., 1991)

Heart Rate	Exertion index	Wisbey's formula: players' instantaneous speed (over 10 s and speed over 60 s).	(Folgado et al., 2015)	(Wisbey et al., 2010)
	HR _{max} (bpm)	Percentage of HR _{max} into intensity zones: Zone 1 (<75% HR _{max}), Zone 2 (75–84.9% HR _{max}), Zone 3 (85–89.9% HR _{max}), and Zone 4 (≥90% HR _{max}).	(Folgado et al., 2018; Sampaio et al., 2014)	(Abt & Lovell, 2009; Gore, 2000)
	Average HR (bpm)	Average beats per minute (BPM)	(Gonçalves et al., 2017)	ND
	TRIMP _{MOD}	Total TRIMP _{MOD} : zone 1 (65–71% HR _{max})*1.25; zone 2 (72–78% HR _{max})*1.71; zone 3 (79–85% HR _{max})*2.54; zone 4 (86–92% HR _{max})*3.61; and zone 5 (93–100% HR _{max})*5.16	(Folgado et al., 2018)	(Campos-Vazquez et al., 2015; Los Arcos et al., 2014; Stagno et al., 2007)

Abbreviations: <math>\overline{qd(t)}> – Dynamic overlap; ACC/DEC – Accelerations and decelerations; ApEn – Approximate entropy; BPM – Average beats per minute; CR-10 – Borg CR10 scale; CV – Coefficient of variation; D – Distance; HR – Heart Rate; HR_{max} – maximum Heart Rate; LPWR – Team width, team length and their ratio or LPW – length-per-width ratio per team; MSE – Multiscale Entropy; PEA – Prediction Ellipse; RPE – Ratings of Perceived Exertion; SamEn – Sample Entropy; SEA – Standard Ellipse; SEI – Spatial exploration index; TD – Total distance; TRIMP – Training Impulse; TRIMP_{MOD} – modified Training Impulse.

Table 6(on next page)

Methodological approaches of included articles.

Methodological approaches of included articles.

Table 6 – Methodological approaches of included articles.

Referente (year)	Study Purpose	Experimental Approach						Methodological procedures	Data Collection (Device specification)	Statistical and mathematical analysis
		Match-play	Training set	Game format	Physical/Physiological	Positional/Tactical	Other dimensions			
Baptista et al. (2020)	Identified the effects of playing formations on tactical behaviour and external workload during SSG.	✗	SSG	GK + 7 vs 7 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	Non-differential 5Hz GPS (ND)	Cohen' <i>d</i> SWC MBI ApEn Voronoi algorithm
Canton et al. (2021)	Identified how positioning the goals in diagonal configurations on the pitch modifies the external training load and the tactical behaviour during SSG.	✗	SSG	GK + 5 vs 5 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA) Lince software® (Gabin et al., 2012),	10 Hz GPS units (WIMU PRO, RealTrack Systems, Almeria, Spain)	Cohen' <i>d</i> SWC MBI NHST
Coutinho et al. (2017)	Examined the effects of mental fatigue and additional corridor and pitch sector lines on players' physical and tactical performances during SSG.	✗	SSG	GK + 6 vs 6 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	CR10-scale (RPE) Portable optical timing system (Optojump, Microgate, Bolzano, Italy) 15Hz GPS (SPIPRO, GPSports, Canberra, ACT, Australia)	Cohen' <i>d</i> SWC NHST
Coutinho et al. (2019)	Identified the effects of adding spatial references during SSG on players' tactical and physical performance.	✗	SSG	GK + 6 vs 6 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-PRO, GPSports, Canberra, ACT, Australia)	CV ApEn MBI NHST
Coutinho et al. (2019)	Identified the effects of different pitch configurations on players' positional and physical performance.	✗	SSG	GK + 5 vs 5 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-PRO, GPSports, Canberra, ACT, Australia)	CV ApEn MBI NHST
Coutinho et al. (2020)	Compared players' performances when manipulating the external markings of the pitch during SSG.	✗	SSG	GK + 5 vs 5 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA) LongoMatch software (Longomatch, version 1.3.7., Fluendo)	5 Hz GPS (SPI-PRO, GPSports, Canberra, ACT, Australia) Digital video camera (Sony NV-GS230)	CV ApEn MBI NHST
Coutinho et al. (2022)	Explored how the number of allowed ball touches per player possession affected the performance of different age groups during SSG.	✗	SSG	GK + 6 vs 6 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA) LongoMatch software (Longomatch, version 1.3.7., Fluendo)	5 Hz GPS (SPI-PRO, GPSports, Canberra, ACT, Australia)	Cohen' <i>d</i> SWC NHST Hilbert transform
Coutinho et al. (2022)	Aimed to identify the effects of playing with additional individual, collective or individual-collective variability on players' performance during SSG.	✗	SSG	GK + 6 vs 6 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA) LongoMatch software (Longomatch, version 1.3.7., Fluendo)	5 Hz GPS (SPI-PRO, GPSports, Canberra, ACT, Australia)	Cohen' <i>d</i> NHST Hilbert transform
Coutinho et al. (2022)	Explored how manipulating the colour of training vests affects footballers' individual and collective performance during SSG.	✗	SSG	GK + 6 vs 6 + GK	✓	✓	✓	Matlab® routines (Math-Works, Inc., Massachusetts, USA) LongoMatch software (Longomatch, version 1.3.7., Fluendo)	5 Hz GPS (SPI-PRO, GPSports, Canberra, ACT, Australia)	Cohen' <i>d</i> NHST Hilbert transform
Ferraz et al. (2020)	Identified how the manipulation of knowledge regarding a training task duration constrains the pacing and tactical behaviour in SSG.	✗	SSG	GK + 5 vs 5 + GK	✓	✓	✓	ND	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia)	ApEn MBI
Figueira et al. (2018)	Compared footballers' performances when playing with teammates and opponents from the same or different age groups	✓	-	GK + 11 vs 11 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia)	CV ApEn MBI
Folgado et al. (2015)	Examined the physical and tactical performances under congested and non-congested fixture periods	✓	-	GK + 11 vs 11 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	Semiautomatic tracking system (Prozone®, ProZone Holdings Ltd, UK).	CHAID Cohen' <i>d</i> NHST Hilbert transform
Folgado et al. (2018)	Identified changes in tactical, physical and physiological performances in LSG during the preseason.	✗	LSG	GK + 8 vs. 8 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia)	NHST Cohen' <i>d</i>
Folgado et al. (2019)	Compared players' performance during two SSG with different pitch orientation (i.e., 40x30m vs 30x40m).	✗	SSG	GK + 4 vs 4 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	10 Hz GPS (Minimax S5, Catapult Innovations, Australia). Digital Video Camera (Canon PowerShot SX720 HS, Canon Inc,	ICC SEM Cohen' <i>d</i> SWC

									Tokyo, Japan),	MBI
Gonçalves et al. (2014)	Identified differences in time–motion, modified training impulse, body load and movement behaviour between defenders, midfielders and forwards, during an 11-a-side simulated football game.	✓	-	GK + 11 vs 11 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia) 1 Hz short-range radio telemetry (Polar Team Sports System, Polar Electro Oy, Finland)	Hilbert transform ApEn NHST
Gonçalves et al. (2017)	Identified how pitch area restrictions affect the players' tactical behavior, physical, and physiological performances during LSG.	✗	LSG	GK + 9 vs. 9 + GK GK+ 10 vs. 10 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia) 1 Hz short-range radio telemetry (Polar Team Sports System, Polar Electro Oy, Finland)	Hilbert transform CV ApEn Cohen' <i>d</i> SWC MBI
Gonçalves et al. (2018)	Examined the changes in the players' speed synchronization and physical performance between the first and the second half (15- min time). Explored the match-to-match variation of players' speed synchronization performance.	✓	-	GK + 11 vs 11 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	Match Analysis Camera System®.	Hilbert transform CV Cohen' <i>d</i> SWC MBI
Jara et al. (2019)	Analyzed how the modification of the pitch size in SSGs affects the GK's physical demands.	✗	SSG MSG LSG	ND	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	18.18 Hz GPS (GPEXE GK, Exelio SRL, Udine, Italy)	Cohen' <i>d</i> MBI NHST
Machado et al. (2022)	Investigated how different strategies of task constraint manipulation impact physical and tactical demands in small-sided and conditioned games (SSCG)	✗	SSG	GK + 4 vs 4 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA) and SPRO™ (RealTrack System, Almeria, Spain)	10 Hz GPS and inertial devices (WIMU Pro™ and GPS, RealTrack System, Almeria, Spain)	Effect size (ND) NHST
Nieto et al. (2022)	Described the effects on player's collective behaviour and physical response in three different pitch lengths (100, 75 and 50 m) keeping the width constant (60 m)	✗	LSG	GK + 11 vs 11 + GK	✓	✓	✗	Microsoft Excel Visual Basic for Applications (VBA) (Microsoft, Redmond, WA, USA)	10 Hz GPS (MinimaxX S5, Catapult Innovations)	Cohen' <i>d</i> MBI NHST SampEn
Olthof et al. (2018)	Investigated SSGs with a traditional small pitch and a match-derived relative pitch area in youth elite soccer players.	✓	SSG	GK + 4 vs 4 + GK GK + 11 vs 11 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	Two HD video dome cameras (Bosch GmbH, Stuttgart, Germany) and one or two high resolution digital cameras (Canon HF100, Canon Inc., Tokyo, Japan; JVC Everio, JVC Kenwood Corporation, Kanagawa, Japan).	NHST Effect sized eta-squared (η_p^2)
									LPM system (Inmotio Object Tracking BV., Amsterdam, the Netherlands)	
Praça et al. (2016)	Compared the collective tactical behavior between numerically balanced and unbalanced SSG.	✗	SSG	3 vs 3 3 vs 3 + 2 4 vs 3	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	15 Hz GPS (model SPI-Pro X2, GPSports, Canberra, Australia)	NHST Effect sized eta-squared (η_p^2)
Praça et al. (2021)	Analysed the effects of changing the match venue on match-related player's physiological, physical, and tactical responses with an age-dependent.	✓	-	GK + 11 vs 11 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	10 Hz GPS device, with an embedded 200 Hz accelerometer and 1 Hz heart rate monitor (Polar®, Team Pro, Kempele, Finland).	NHST Effect sized eta-squared (η_p^2)
(Ric. et al., 2016)	Identified the dynamics of tactical behaviour emerging on different timescales in SSG. Quantified short- and long-term exploratory behaviour according to the number of opponents.	✗	SSG	GK + 4 vs 3 + GK GK + 4 vs 5 + GK GK + 4 vs 7 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	Digital video camera for video recording and analysed an ad hoc instrument being used to notate tactical actions (Costa et al. 2011)	Dynamic overlap <qd(t)> Trapping strength Boltzmann–Gibbs–Shannon entropy NHST Cohen' <i>d</i>
								Lince software® (Gabi net al., 2012)	15 Hz GPS (SPI-ProX, GPS ports, Canberra, ACT, and Australia)	
(Ric et al., 2017)	Identified how players' spatial restrictions affected the exploratory tactical behaviour and constrained the perceptual-motor workspace in ball possession and the inter-player	✗	ND	GK + 10 vs 9 + GK	✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia)	Dynamic overlap <qd(t)>

passing interactions.										
(Sampaio et al., 2014)	Compared and discriminate the time-motion variables, heart rate and players' tactical behaviour according to game pace, status and team unbalance.	✖	SSG	GK + 5 vs 5 + GK	✓	✓	✖	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia)	NHST SC
<div>Abbreviations: <math>\Delta t</math> – Dynamic overlap; ApEn – Approximate entropy; CHAID – Chi-squared automatic interaction detection; Cohen's d – Standardized (Cohen) differences; CV – Coefficient of variation; GK – Goalkeeper; ICC – Intraclass correlation; LSG – Large-sided games; MBI – Magnitude-based inferences; MSG – Medium-sided games; ND – Not described; NHST – Null hypothesis statistical test; η_p^2 – Effect sized eta-squared; SampEn – Sample Entropy; SC – Structural coefficients; SEM – Standard error of measurement; SSG – Small-sided games; SWC – Smallest worthwhile changes; USA – United States; VSA – Visual Basic for Applications.</div>										

Figure 1

PRISMA flow diagram

