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

José E. Teixeira [1, 2], **Pedro Forte** [1, 2, 3], **Ricardo Ferraz** [1, 4], **Luís Branquinho** [4], **António Silva** [1, 5], **António M. Monteiro** [2], **Tiago M Barbosa** [Corresp. 6]

[1] Research Centre in Sports Sciences, Health and Human Development, Vila Real, Portugal

[2] Instituto Politécnico de Bragança, Bragança, Portugal

[3] Institute of Educational Sciences, Penafiel, Portugal

[4] University of Beira Interior, Covilhã, Portugal

[5] University of Trás-os-Montes and Alto Douro, Vila Real, Portugal

[6] Sport Sciences, Polytechnic Institute of Bragança, Bragança, Portugal

Corresponding Author: Tiago M Barbosa
Email address: barbosa@ipb.pt

Background: Positional data have been used to capture physical, physiological and tactical factors in football. However, previous systematic reviews captured the tactical behaviours without considering the integration of the different performance dimensions. Thus, the aim of this article was to systematically review the published articles that encompass physical, physiological 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/physiological 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 ($n = 5$). 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 and physiological data can be integrated by player's movement speed, heart-rate based measures and perceived

exertion. Positional datasets can be computed by spatial movement variability/regularity, complex index, coordination/synchronization using intra-team and inter-team dyads, playing space. Futures researches should consider applying positional data in women's football environments and explore the representativeness of the MSG and LSG.

1 **Title page**

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Abstract

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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/physiological 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 ($n = 5$). 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 and physiological data can be integrated by player's movement speed, heart-rate based measures and perceived exertion.

27   Positional datasets can be computed by spatial movement variability/regularity, complex index,

28   coordination/synchronization using intra-team and inter-team dyads, playing space. Futures

29   researches should consider applying positional data in women's football environments and explore

30   the representativeness of the MSG and LSG.

31   **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 and physiological demands on the tactical behaviour (Carrilho et al., 2020; F. M. 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

55 computer science based on big data methodology, using new computational procedures to extract,

56 process and analyse data with practical applicability for training and match performance (Rico-

57 González et al., 2021). However, most of the scientific production is based exclusively on physical

58 and physiological performance without giving a contextual and behavioural significance to the

59 players' movements (Teixeira et al., 2022). Moreover, performance analysis in football needs a

60 multidimensional approach to capture the adaptive individual and collective behaviour (Carling et

61 al., 2014; Gonçalves et al., 2019). These multifactorial phenomenon depends on a physical,

62 tactical, and technical factors with a not each performance factor is not mutually exclusive of one

63 another (Bradley & Ade, 2018; Paul et al., 2015).

64   Currently, a growing reviews and meta-analysis have been published on this research topic

65 focusing on training and match insights (Low et al., 2020; Rago et al., 2020; Teixeira et al., 2021).

66 However, reviewing articles have considered each performance factor independently, describing

67 tactical behaviour separately from physical and physiological demands. Also, previous systematic

68 reviews captured the tactical behaviours without considering the integration of the different

69 performance dimensions (Coito et al., 2022; Ometto et al., 2018). To the best of our knowledge,

70 no attempts have been made to review the state of art concerning that included integrative

71 approaches to emphasize the positional data collected through tracking systems regarding physical,

72 physiological and tactical variables. Thus, a lack of the absence of procedural standardization to

73 apply positional data in an integrative approach (Teixeira et al., 2022). Thus, the aim of this study

74 was to systematically review the published articles that integrate physical, physiological and

75 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) (Moher et al., 2009). 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 (Moher et al., 2009). 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/physiological and tactical measures using spatiotemporal datasets; (3) Comparison: physical, physiological and tactical variables (4) *Outcomes*: tracking, positional and time-series

97 data; (5) *Study design*: original experimental and quasi-experimental trials (e.g., randomized

98 controlled trial, cohort studies or cross-sectional studies).

99 On this basis, the inclusion criteria used for the article selection were: (1) original article

100 focused on adult and youth football players of both sexes; (2) studies with screening procedures

101 based on physical, physiological and tactical measures using tracking and positional data; (3)

102 studies that used spatiotemporal to assess physical and physiological; (4) studies that used

103 positional and tracking data to measures spatiotemporal and tactical variables through time-series;

104 (3) other performance factors as psychophysiological, technical and contextual factors were not

105 excluded from the present review only if both variables of interest (i.e. physical, physiological and

106 tactical measures) were also part of the experimental design; (5) studies of human physical and

107 physiological performance in Sport Science and as scope; (6) original article published in a peer-

108 review journal; (7) full text available in English; (8) article reported sample and screening

109 procedures (e.g. data collection, study design, instruments, and the outcomes).

110 Otherwise, the exclusion criteria were: (1) original articles individual and others team

111 sports as football code population (e.g. Australian Football, Gaelic Football, Union and/or Seven

112 Rugby); (2) studies that study that analysed none or only one of the target performance factors (i.e.

113 physical/physiological or tactical measures); (3) studies which integrate several performance

114 factors, but do not combine the two variables of interest even if one of them is integrated; (4)

115 studies that measured physical and physiological using on field based test and laboratory test rather

116 than tracking and positional data; (5) studies that included tactical variables using notational

117 analysis and other methodological procedures that do not assess spatiotemporal and positional

118 data through time-series; (6) others research areas and non-human participants; (7) articles with

119 bad quality in the description of study sample and screening procedures (e.g. data collection, study

120 design, instruments, and the measures) according to PEDro and Downs and Black scales; (8)

121 reviews, abstract/papers conference, surveys, opinion pieces, commentaries, books, periodicals,

122 editorials, case studies, non-peer-reviewed text, masters and/or doctoral thesis.

123 **2.3.   Quality Assessment**

124 The methodological quality was assessed using the modified Downs and Black Quality Index

125 (cross-sectional studies) and the Physiotherapy Evidence Database (PEDro) scale (intervention

126 studies) based on previous systematics reviews (Bujalance-Moreno et al., 2019, Rago et al., 2020).

127 Quality Assessment was independently performed by two authors (J.E.T, P.F.) with subsequent

128 inter-observer reliability analysis (Kappa index: 0.91; 95% IC: 0.90–0.92) (Table 3).

129 **2.4. Study Coding and Data Extraction**

130 **3.** The data extraction of the reviewed articles were organized into the following topics: (1)

131 sampling characteristics by the study design, population, competitive level, sample (N), sex, age,

132 expertise level and quality score (Table 3): (2) summary of performance dimension, measures,

133 measurement, thresholds and/or metric formula in the reviewed articles; references and 'further

134 reading' reports the original studies where the methodology of the included articles were based

135 (Table 4); (3) methodological approaches of the reviewed studies by reporting the study purpose,

136 experimental approach, methodological procedures, data collection, statistical and mathematical

137 analysis (Table 5). Data were collected as previously described in 'The Cochrane Data Extraction

138 Template for Included Studies' using a Microsoft Excel sheet (Microsoft Corporation, Readmon,

139 WA, USA (Synnot et al., 2020). **Results**

140 **3.1. Search Results and Study Selection**

141   Table 2 showed the search results in each databases according to keywords organized by PICOS

142   approach. A total of 982 titles were collected through three database searches (WoS = 495; Pub-

143   Med = 232 and SportDiscus = 255).

144   **[PLACE TABLE 2 HERE]**

145   After applying the selection criteria, 153 full-text articles were assessed for eligibility, having

146   selected 26 articles for final revision. Figure 1 showed the search results using PRISMA flow

147   diagram with screening procedures and search results.

148   **[PLACE FIGURE 1 HERE]**

149 3.2.   Participant Characteristics

150   The reviewed articles were published between 2000 and 2022. Studies samples were ranged

151   between 8–148 participants with an observational, prospective and cross-sectional design ($n = 8$)

152   and randomized controlled trial (n = 18). Twenty-three articles were focused on adult football

153   players and seven on youth population.. All articles were performed on male football players,

154   specifically in elite ($n = 2$), professional ($n = 8$), high-level ($n = 1$), national level ($n = 2$), amateur

155   ($n = 2$) and volunteer ($n = 1$) contexts. A total of 538 football players were analysed in this

156   systematic review. Age and expertise level in the included studies was 16.81 ± 1.63 and 4.2 ± 3.83

157   years, respectively. Table 3 provides the sampling characteristics of the reviewed studies.

158   **[PLACE TABLE 3 HERE]**

159 3.3. Quality Assessment

160   In the evaluation of methodological quality, the mean quality score and standard deviation of all

161   the included studies was 4.92, ranging between 3 (lowest quality) to 7 (highest quality) points of

162   maximum score of 8 in the qualitative assessment (Table 3).

163   **3.4. Main Findings**

164   Table 4 presented the data extraction of the reviewed studies. Concerning the physical and

165   physiological datasets, the measures considered were external load (i.e., movement speed) and

166   internal load (i.e., heart rate-based methods), specifically: (i) total distance covered ($n = 11$), (ii)

167   distance covered at different speed zones ($n = 13$), (iii) game pace or average speed ($n = 3$), (iv)

168   accelerations and decelerations ($n = 3$), (v) locomotive-based ratios (e.g., ratio between the

169   distance covered at different intensities and distance) ($n = 1$), (vi) exertion-based indexes (i.e.,

170   exertion index per minute, ratings of perceived exertion) ($n = 1$) and (vii) heart rate-based methods

171   (i.e., $\%HR_{max}$, $TRIMP_{MOD}$) ($n = 3$). Otherwise, positional and tactical variables reported in the

172   included studies was based on the following independent variables: (i) possession ball ($n = 1$), (ii)

173   spatial exploration indexes ($n = 6$), (iii) LPW ratio ($n = 1$), (iv) stretch indexes ($n = 2$), (v)

174   multiscale entropy ($n = 1$), (vi) synchronization indexes (i.e., longitudinal and lateral directions)

175   ($n = 10$), (v) intra-team and opponent's dyads ($n = 3$), (vi) dispersion and contraction indexes (i.e.,

176   length, width and speed) ($n = 4$), (vii) playing space and effectiveness (i.e., effective playing space,

177   longitudinal distance between GK and the closest defender ($n = 3$), (viii) player's variability,

178   regularity and coordination ($n = 10$) (i.e., entropy, dynamic overlap, near-in-phase and near-anti-

179   phase coordination, regularity zones occupied), (ix) team centroid ($n = 2$).

180   Table 5 showed the study purpose, game format, experimental approach, methodological

181   procedures, data collection, statistical and mathematical analysis of the included studies in this

182   review (Table 4). The data organization respected the main purposes of this systematic review,

183   specifically the integration of physical/physiological and tactical variables in football using

184   positional data ($n = 26$). Other dimensions were also reported, such as psychological and technical

185   factors, however the results of these approaches were not the focus of the analysis ($n = 5$). Quasi-

186   experimental approaches considered training sets ($n = 20$) and match contexts ($n = 6$). One study

187   analysed both training and play insights. Small sided-games (SSG) were the most common training

188   task formats in the reviewed studies, with only three articles addressing medium-sided (MSG) (n

189    $= 1$) and large-sided games (LSG) ($n = 2$), respectively. Regarding the methodological procedures,

190   Matlab® routines (Math-Works, Inc., Massachusetts, USA) were used by all authors for

191   processing raw data (xx, yy) (n = 26). All studies applied Butterworth low pass filter at frequency

192   sampling ranged between 3–5 Hz using 10–20 windows and 1000–3000 points per data collect.

193   Match analysis software were applied for to extract technical variables into three studies,

194   specifically the LongoMatch® software ($n = 1$), Match Analysis Camera Systems® ($n = 1$) and

195   Lince software ($n = 1$). Data collection was based on GPS ($n = 15$), LPM ($n = 2$) and optical-

196   based tracking systems ($n = 5$) ranging from 5 to 15 Hz. Also, internal training load measures was

197   collected by 1 Hz short-range radio telemetry ($n = 2$) and CR 10-scale ($n = 1$). A study used

198   portable optical timing system to measure neuromuscular performance (i.e., countermovement

199   jump, CMJ).

200   A null hypothesis statistical test (NHST) and magnitude-based inferences (MBI) in seven

201   studies ($n = 7$) and five studies ($n = 5$), respectively. The statistical and mathematical analysis

202   performed in the reviewed reports were the approximate entropy (ApEn) ($n = 7$), Boltzmann–

203   Gibbs–Shannon entropy measure ($n = 7$), Coefficient of variation (CV) ($n = 7$), dynamic overlap

204   ($<qd(t)>$) ($n = 7$), effect sized Cohen d ($n = 7$), effect sized eta-squared (η_p^2) ($n = 7$), hilbert

205   transform ($n = 7$), intraclass correlation (ICC) ($n = 7$), smallest worthwhile changes (SWC) ($n =$

206   7), standard error of measurement (SEM) ($n = 7$), standardized (Cohen) differences ($n = 7$),

207   structural coefficients (SC) ($n = 7$), and trapping strength ($n = 7$).

208   **[PLACE TABLE 4 HERE]**

209   **[PLACE TABLE 5 HERE]**

4. Discussion

The aim of this study was to systematically review the published articles that integrate physical, physiological and tactical variables in football using positional data. Earliest, the physical and physiological data was analysed by the player's movement speed, heart-rate based measures and perceived exertion. Otherwise, positional datasets was computed by individual and team collective behaviour expressed using spatio-temporal 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 and physiological 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; Sarmento et al., 2018).

233   Moreover, the reviewed quasi-experimental approaches considered training sets and match

234   contexts. Small sided-games (SSG) were the most common training task formats in the reviewed

235   studies, with only three articles addressing medium-sided (MSG) and large-sided games (LSG)

236   (Machado et al., 2020; Folgado et al., 2018; Gonçalves et al., 2017; Jara et al., 2019; Nieto et al.,

237   2022; Praça et al., 2016), respectively. Thus, the SSG formats have been further explored in the

238   literature, mainly through the 5- and 6-sided game format. Indeed, these SSG-based formats was

239   previous reported as an useful tool to promote into significant variations in the training load, and

240   in the likely improvement of the different domains of soccer training (i.e., physiological, technical,

241   and tactical dimensions) (Branquinho & Marques, 2021; Clemente et al., 2021). Also, SSG and

242   conditioned games (SSCG) are an excellent form to enhance acquisition of motor efficiency and

243   decision-making skills (Davids et al., 2013). A widespread research gap remains unexplored in

244   MSG and LSG formats, as well as their relationship with formal game formats (i.e., 7-, 8-, 9- and

245   11-sided formats) (Baptista et al., 2020; Coutinho et al., 2019, 2020; Ferraz et al., 2020; Figueira

246   et al., 2018; Gonçalves et al., 2017; Sampaio et al., 2014).

247   Regarding the methodological procedures, Matlab® routines (Math-Works, Inc.,

248   Massachusetts, USA) were applied to process raw data (xx, yy) ($n = 26$), transforming data points

249   in the Universal Transverse Mercator (UTM) coordinate system (Folgado et al., 2014; Sampaio &

250   Maças, 2012). The most used correction guidelines to reduce tracking signal noise was a 3 Hz

251   Butterworth low pass filter by applying a non-linear logarithms using 20 windows of 3000 points

252   per data collect (Coutinho et al., 2019, 2020; Figueira et al., 2018; Folgado et al., 2015, 2019;

253   Gonçalves et al., 2017, 2018). Other studies used smaller data windows such as 1500 data sets

254   and a sampling frequency for signal correction (i.e., 5Hz) (Baptista et al., 2020). Nevertheless, the

255   sampling frequency and datasets is highly dependent on the type of non-linear method to be used,

256 and the use of higher time-series lengths can increase the consistency of the positional data

257 (Baptista et al., 2020; Richman & Moorman, 2000; Yentes et al., 2013). Approximate entropy

258 (ApEn) was the most applied non-linear method for measuring the spatial movement

259 variability/regularity (Baptista et al., 2020; Coutinho et al., 2019, 2020; Ferraz et al., 2020;

260 Figueira et al., 2018; Gonçalves et al., 2017; Sampaio et al., 2014). Also, stretch index can be

261 based on the ApEn or distance, being the most reported complex index in the reviewed literature

262 (Coutinho et al., 2019; Olthof et al., 2018; Praça et al., 2021). Indeed, the entropy has been

263 extensively reported as outstanding informational parameter to describe the variability and

264 predictability of the players' movement (Teixeira et al., 2022). Hilbert transform was the most

265 frequent method, by computing the longitudinal and lateral directions through in- and anti-phase

266 (Coutinho et al., 2019, 2020;; Fernandes et al., 2010; Figueira et al., 2018; Folgado et al., 2015,

267 2019; Gonçalves et al., 2017, 2018). Total surface area or playing space (m^2) can be provided

268 through trigonometry using the smallest convex hull and/or polygonal area delimited by the

269 peripheral players (Coutinho et al., 2017; Folgado et al., 2019; Olthof et al., 2018). Recently,

270 Teixeira et al. (2022) reported what remains to be explored correlation matrixes, clustering

271 methods and fractality patterns. This review confirms this and opens up the possibility of exploring

272 these metrics by integrating physical and physiological demands with individual and collective

273 behaviour.

274   Match analysis software were applied in reviewed three studies for notational analysis to

275 extract technical variables, specifically the LongoMatch® software, Match Analysis Camera

276 Systems® (Gonçalves et al., 2018) and Lince software (Canton et al., 2021; Ric et al., 2016).

277 Further tactical variables was applied in the reviewed studies using other methodological

278 approaches (i.e., observational and notational analysis) such as metrics based on ball possession,

279   team networks and tactical actions classifications. Technical outcomes were mainly based on

280   individual actions and skills characterized in quantity and success (i.e., successful passes, dribbles

281   and shots) (Coutinho et al., 2020, 2022a; 2022b; 2022c; Folgado et al., 2019; Olthof et al., 2018;

282   Ric et al., 2017). Data collection was based on GPS, LPM and optical-based tracking systems

283   ranging from 5 to 18 Hz. The first studies were mainly based on 5 Hz GPS (SPI-Pro X II, GPS

284   ports, Canberra, ACT, and Australia), however the use of sampling frequency at 5Hz must consider

285   some limitations in the measurement of non-linear and high-intensity paths (Portas et al., 2010;

286   Teixeira et al., 2021). Authors should prioritise tracking devices with sampling frequencies above

287   10 Hz shape with an accelerometer (Gómez-Carmona et al., 2020; Rico-González et al., 2020).

288   The latest GPS devices already recommend a sampling frequency of 10-18Hz, specifically 10 Hz

289   GPS units (WIMU PRO, RealTrack Systems, Almeria, Spain) (Canton et al., 2021; Machado et

290   al., 2022), 10 Hz GPS (S5, Catapult Innovations, Australia) (Folgado et al., 2019; Nieto et al.,

291   2022), 10 Hz GPS (Polar, Team Pro, Kempele, Finland) (Praça et al., 2021), 15Hz GPS (SPIPRO,

292   GPSports, Canberra, ACT, Australia) (Coutinho et al., 2017; Praça et al., 2016; Ric et al., 2016)

293   and 18.18 Hz GPS (GPEXE GK, Exelio SRL, Udine, Italy) (Jara et al., 2019). LPM devices and

294   semiautomatic video tracking system used in the surveyed studies were the Prozone® (ProZone

295   Holdings Ltd, UK) (Folgado et al., 2015) and the Inmotio Object Tracking® (BV., Amsterdam, the

296   Netherlands) (Olthof et al., 2018). The integration of the different tracking systems can be further

297   explored from an integrative perspective (Buchheit et al., 2014; Linke et al., 2018). Also, the

298   relationship between objective (i.e., tracking systems) and subjective (i.e., observational/notational

299   analysis) measures should be explored in future integrative approaches, in order to make the

300   integration of technical and tactical factors more effective (Teixeira et al., 2021b). Likewise,

301   internal training load was collected by heart-rate-based measures and perceived exertion. Although

302 some limitations have been reported in some studies, the perceived exertion and heart-rate

303 maintains its applicability for elite and sub-elite football contexts, and is lower cost and more easily

304 implemented (Achten & Jeukendrup, 2003; Teixeira et al., 2022; Teixeira, Forte, et al., 2021b). A

305 study used portable optical timing system to measure neuromuscular performance (i.e.,

306 countermovement jump, CMJ). The field-based tests in football becomes more effective when

307 continuous control (i.e. monitoring) is integrated into the assessment (Clemente et al., 2022;

308 Gomez-Carmona et al., 2020).

309   A null hypothesis statistical test (NHST) and magnitude-based inferences (MBI) in seven

310 studies and five studies, respectively. Some authors used joint approaches for their data handling,

311 as well as statistical analysis such as coefficient of variation (CV) ($n = 7$), effect sized (ES) and

312 smallest worthwhile changes (SWC) (Bernards et al., 2017; Flanagan, 2013).The application of

313 the two statistical approaches makes it more difficult to compare results of the availed studies, and

314 future studies should further analyse the potential overvaluation and bias of the study findings

315 (Foster et al., 2017; Welsh & Knight, 2015). Bringing NHST and MBI approaches together may

316 be a valid approach to avoid overestimating outcomes (Welsh & Knight, 2015).

317   The current systematic review has some limitations should be consider. First, the

318 interpretation of the studies was only qualitative, not considering meta-analysis. Second, the fact

319 that only studies that integrated the physical, physiological and tactical variables and not just one

320 dimension. For this reason, other information about physiological and behavioural data may have

321 been absent (Duarte et al., 2013; Folgado et al., 2014; Vilar et al., 2014). Although this was made

322 objective in the inclusion and exclusion criteria, future systematic reviews should clarify which

323 studies used both one-dimensional and integrative approach. As practical applications and futures

324 researches, there are some future topics that could be explored specifically: (i) the development of

325   friendly-user interfaces, in order to disseminate positional data until now almost exclusively to

326   Matlab® routines processing (Math-Works, Inc., Massachusetts, USA); (ii) developing tracking

327   and wearables devices which enable real-time feedback to increase the practical applicability and

328   decision making of football players and coaching staff; (iii) applying advanced data analytics and

329   big data-based methods using artificial intelligence (AI), machine learning (ML) and deep learning

330   to compute automatically physiological and positional data; (iv) manipulating task constraints in

331   MSG, LSG and different game-formats can still be better exploited; woman's football is still not

332   analysed using physical, physiological and tactical integration.

333   **5. Conclusions**

334   Among the current systematic review, the physical and physiological data can be integrated by

335   player's movement speed, heart-rate based measures and perceived exertion. Positional datasets

336   can   be   computed   by   spatial   movement   variability/regularity,   complex   index,

337   coordination/synchronization using intra-team and inter-team dyads, playing space. Futures

338   researches should consider applying positional data in women's football environments and explore

339   the representativeness of the MSG and LSG.

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/ijspp.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

Batshcelet, 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/ijspp.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/ijspp.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

382 Branquinho, L., Ferraz, R., Travassos, B., Marinho, D. A., & Marques, M. C. (2021). Effects of different
383   recovery times on internal and external load during small-sided games in soccer. *Sports Health*,
384   1941738121995469. https://doi.org/10.1177/1941738121995469

385 Branquinho, L., Ferraz, R., Travassos, B., & Marques, M. C. (2020). Comparison between continuous and
386   fractionated game format on internal and external load in small-sided games in soccer. *International*
387   *Journal of Environmental Research and Public Health*, *17*(2), 405.
388   https://doi.org/10.3390/ijerph17020405

389 Buchheit, M., Allen, A., Poon, T. K., Modonutti, M., Gregson, W., & Salvo, V. D. (2014). Integrating
390   different tracking systems in football: Multiple camera semi-automatic system, local position
391   measurement and GPS technologies. *Journal of Sports Sciences*, *32*(20), 1844–1857.
392   https://doi.org/10.1080/02640414.2014.942687

393 Busa, M. A., & van Emmerik, R. E. A. (2016). Multiscale entropy: A tool for understanding the complexity
394   of postural control. *Journal of Sport and Health Science*, *5*(1), 44–51.
395   https://doi.org/10.1016/j.jshs.2016.01.018

396 Campos-Vazquez, M. A., Mendez-Villanueva, A., Gonzalez-Jurado, J. A., León-Prados, J. A., Santalla, A.,
397   & Suarez-Arrones, L. (2015). Relationships between rating-of-perceived-exertion- and heart-rate-
398   derived internal training load in professional soccer players: A comparison of on-field integrated
399   training sessions. *International Journal of Sports Physiology and Performance*, *10*(5), 587–592.
400   https://doi.org/10.1123/ijspp.2014-0294

401 Canton, A., Torrents, C., Gonçalves, B., Ric, A., Salvioni, F., Exel, J., & Sampaio, J. (2021). The diagonal
402   positioning of the goals modifies the external training load and the tactical behaviour of young football
403   players. *Biology of Sport*, *39*(1), 135–144. https://doi.org/10.5114/biolsport.2021.102929

404 Carling, C., Wright, C., Nelson, L. J., & Bradley, P. S. (2014). Comment on 'Performance analysis in
405   football: A critical review and implications for future research'. *Journal of Sports Sciences*, *32*(1), 2–
406   7. https://doi.org/10.1080/02640414.2013.807352

407 Carrilho, D., Santos Couceiro, M., Brito, J., Figueiredo, P., Lopes, R. J., & Araújo, D. (2020). Using Optical
408   Tracking System Data to Measure Team Synergic Behavior: Synchronization of Player-Ball-Goal
409   Angles in a Football Match. *Sensors*, *20*(17), 4990. https://doi.org/10.3390/s20174990

410 Castellano, J., Alvarez-Pastor, D., & Bradley, P. S. (2014). Evaluation of research using computerised
411   tracking systems (Amisco and Prozone) to analyse physical performance in elite soccer: A systematic
412   review. *Sports Medicine (Auckland, N.Z.)*, *44*(5), 701–712. https://doi.org/10.1007/s40279-014-0144-
413   3

414 Clemente, F. M., Afonso, J., Castillo, D., Arcos, A. L., Silva, A. F., & Sarmento, H. (2020). The effects of
415   small-sided soccer games on tactical behavior and collective dynamics: A systematic review. *Chaos,*
416   *Solitons & Fractals*, *134*, 109710. https://doi.org/10.1016/j.chaos.2020.109710

417 Clemente, F. M., Afonso, J., & Sarmento, H. (2021). Small-sided games: An umbrella review of systematic
418   reviews and meta-analyses. *PLOS ONE*, *16*(2), e0247067.
419   https://doi.org/10.1371/journal.pone.0247067

420 Clemente, F. M., Couceiro, M. S., Martins, F. M. L., Mendes, R., & Figueiredo, A. J. (2013). Measuring
421   tactical behaviour using technological metrics: Case study of a football game. *International Journal*
422   *of Sports Science & Coaching*, *8*(4), 723–739. https://doi.org/10.1260/1747-9541.8.4.723

423 Clemente, F. M., Owen, A., Mustapha, A., van der Linden, C. M. I. (Niels), Ribeiro, J., Mendes, B., &
424   Reichert, J. (2018). Measurement of the Pitch Exploration Amongst Elite Professional Soccer Players:
425   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. (2022). 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. (2022). 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. (2022). 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

470 Coutts, A. J., & Duffield, R. (2010). Validity and reliability of GPS devices for measuring movement
471   demands of team sports. *Journal of Science and Medicine in Sport*, *13*(1), 133–135.
472   https://doi.org/10.1016/j.jsams.2008.09.015

473 Dalen, T., Jørgen, I., Gertjan, E., Geir Havard, H., & Ulrik, W. (2016). Player load, acceleration, and
474   deceleration during forty-five competitive matches of elite soccer. *The Journal of Strength &*
475   *Conditioning Research*, *30*(2), 351–359. https://doi.org/10.1519/JSC.0000000000001063

476 David Gomez-Carmona, C., Pino-Ortega, J., & Jose Ibanez, S. (2020). Design and validity of a field test
477   battery for assessing multi-location external load profile in invasion team sports. *E-Balonmano Com*,
478   *16*(1), 23–48.

479 Davids, K., Araújo, D., Correia, V., & Vilar, L. (2013). How Small-Sided and Conditioned Games Enhance
480   Acquisition of Movement and Decision-Making Skills. *Exercise and Sport Sciences Reviews*, *41*(3),
481   154–161. https://doi.org/10.1097/JES.0b013e318292f3ec

482 Di Salvo, C., & Marco, C. (2006). Validation of Prozone ®: A new video-based performance analysis
483   system. *International Journal of Performance Analysis in Sport*, *6*(1), 108–119.
484   https://doi.org/10.1080/24748668.2006.11868359

485 Duarte, R., Araújo, D., Correia, V., & Davids, K. (2012). Sports teams as superorganisms: Implications of
486   sociobiological models of behaviour for research and practice in team sports performance analysis.
487   *Sports Medicine*, *42*(8), 633–642. https://doi.org/10.1007/BF03262285

488 Duarte, R., Araújo, D., Correia, V., Davids, K., Marques, P., & Richardson, M. J. (2013). Competing
489   together: Assessing the dynamics of team–team and player–team synchrony in professional association
490   football. *Human Movement Science*, *32*(4), 555–566. https://doi.org/10.1016/j.humov.2013.01.011

491 Duarte, R., Araújo, D., Davids, K., Travassos, B., Gazimba, V., & Sampaio, J. (2012). Interpersonal
492   coordination tendencies shape 1-vs-1 sub-phase performance outcomes in youth soccer. *Journal of*
493   *Sports Sciences*, *30*(9), 871–877. https://doi.org/10.1080/02640414.2012.675081

494 Duarte, R., Araújo, D., Folgado, H., Esteves, P., Marques, P., & Davids, K. (2013). Capturing complex,
495   non-linear team behaviours during competitive football performance. *Journal of Systems Science and*
496   *Complexity*, *26*(1), 62–72. https://doi.org/10.1007/s11424-013-2290-3

497 Duarte, R., Araújo, D., Freire, L., Folgado, H., Fernandes, O., & Davids, K. (2012). *Intra- and inter-group*
498   *coordination patterns reveal collective behaviors of football players near the scoring zone*.
499   https://doi.org/10.1016/j.humov.2012.03.001

500 Fernandes, O., Folgado, H., Duarte, R., & Malta, P. (2010). Validation of the tool for applied and contextual
501   time-series observation. *International Journal of Sport Psychology*, *41*, 63–64.

502 Ferraz, R., Forte, P., Branquinho, L., Teixeira, J., Neiva, H., Marinho, D., & Marques, M. (2022). *The*
503   *Performance during the Exercise: Legitimizing the Psychophysiological Approach*.
504   https://doi.org/10.5772/intechopen.102578

505 Ferraz, R., Gonçalves, B., Coutinho, D., Marinho, D. A., Sampaio, J., & Marques, M. C. (2018). Pacing
506   behaviour of players in team sports: Influence of match status manipulation and task duration
507   knowledge. *PLoS One*, *13*(2), e0192399. https://doi.org/10.1371/journal.pone.0192399

508 Ferraz, R., Gonçalves, B., Coutinho, D., Oliveira, R., Travassos, B., Sampaio, J., & Marques, M. C. (2020).
509   Effects of knowing the task's duration on soccer players' positioning and pacing behaviour during
510   small-sided games. *Int. J. Environ. Res. Public Health*, 11.

511 Ferraz, R., Gonçalves, B., Tillaar, R., Saiz, S., Sampaio, J., & Marques, M. (2017). Effects of knowing the
512   task duration on players' pacing patterns during soccer small-sided games. *Journal of Sports Sciences*,
513   *36*. https://doi.org/10.1080/24733938.2017.1283433

514 Figueira, B., Gonçalves, B., Masiulis, N., & Sampaio, J. (2018). Exploring how playing football with
515   different age groups affects tactical behaviour and physical performance. *Biology of Sport*, *35*(2), 145–
516   153. https://doi.org/10.5114/biolsport.2018.71603

517 Flanagan, E. P. (2013). The Effect Size Statistic—Applications for the Strength and Conditioning Coach.
518   *Strength & Conditioning Journal*, *35*(5), 37–40. https://doi.org/10.1519/SSC.0b013e3182a64d20

519 Folgado, H., Bravo, J., Pereira, P., & Sampaio, J. (2019). Towards the use of multidimensional performance
520   indicators in football small-sided games: The effects of pitch orientation. *Journal of Sports Sciences*,
521   *37*(9), 1064–1071. https://doi.org/10.1080/02640414.2018.1543834

522 Folgado, H., Duarte, R., Fernandes, O., & Sampaio, J. (2014). Competing with lower level opponents
523   decreases intra-team movement synchronization and time-motion demands during pre-season soccer
524   matches. *PloS One*, *9*(5), e97145. https://doi.org/10.1371/journal.pone.0097145

525 Folgado, H., Duarte, R., Marques, P., & Sampaio, J. (2015). The effects of congested fixtures period on
526   tactical and physical performance in elite football. *Journal of Sports Sciences*, *33*(12), 1238–1247.
527   https://doi.org/10.1080/02640414.2015.1022576

528 Folgado, H., Gonçalves, B., & Sampaio, J. (2018). Positional synchronization affects physical and
529   physiological responses to preseason in professional football (soccer). *Research in Sports Medicine*,
530   *26*(1), 51–63. https://doi.org/10.1080/15438627.2017.1393754

531 Folgado, H., Lemmink, K. A. P. M., Frencken, W., & Sampaio, J. (2014). Length, width and centroid
532   distance as measures of teams tactical performance in youth football. *European Journal of Sport
533   Science*, *14 Suppl 1*, S487-492. https://doi.org/10.1080/17461391.2012.730060

534 Fonseca, S., Milho, J., Travassos, B., & Araújo, D. (2012). Spatial dynamics of team sports exposed by
535   Voronoi   diagrams.   *Human   Movement   Science*,   *31*(6),   1652–1659.
536   https://doi.org/10.1016/j.humov.2012.04.006

537 Foster, C., Rodriguez-Marroyo, J., & de Koning, J. (2017). Monitoring Training Loads: The Past, the
538   Present, and the Future. *International Journal of Sports Physiology and Performance*, *12*, 2–8.

539 Frencken, W., De Poel, H., Visscher, C., & Lemmink, K. A. P. M. (2012). Variability of inter-team
540   distances associated with match events in elite-standard soccer. *Journal of Sports Sciences*, *30*, 1207–
541   1213. https://doi.org/10.1080/02640414.2012.703783

542 Frencken, W., Lemmink, K., Delleman, N., & Visscher, C. (2011). Oscillations of centroid position and
543   surface area of soccer teams in small-sided games. *European Journal of Sport Science*, *11*(4), 215–
544   223. https://doi.org/10.1080/17461391.2010.499967

545 Gabin, B., Camerino, O., Anguera, M. T., & Castañer, M. (2012). Lince: Multiplatform Sport Analysis
546   Software.   *Procedia   -   Social   and   Behavioral   Sciences*,   *46*,   4692–4694.
547   https://doi.org/10.1016/j.sbspro.2012.06.320

548 Giménez, J. V., Del-Coso, J., Leicht, A. S., & Gomez, M.-Á. (2018). Comparison of the movement patterns
549   between small- and large-sided game training and competition in professional soccer players. *The
550   Journal of Sports Medicine and Physical Fitness*, *58*(10), 1383–1389. https://doi.org/10.23736/S0022-
551   4707.17.07343-1

552 Gómez-Carmona, C. D., Bastida-Castillo, A., Ibáñez, S. J., & Pino-Ortega, J. (2020). Accelerometry as a
553   method for external workload monitoring in invasion team sports. A systematic review. *PLOS ONE*,
554   *15*(8), e0236643. https://doi.org/10.1371/journal.pone.0236643

555 Gonçalves, B., Coutinho, D., Exel, J., Travassos, B., Peñas, C., & Sampaio, J. (2019). Extracting spatial-
556   temporal features that describe a team match demands when considering the effects of the quality of
557   opposition in elite football. *PLOS ONE*, *14*, e0221368. https://doi.org/10.1371/journal.pone.0221368

558 Gonçalves, B., Coutinho, D., Travassos, B., Folgado, H., Caixinha, P., & Sampaio, J. (2018). Speed
559   synchronization, physical workload and match-to-match performance variation of elite football
560   players. *PloS One*, *13*(7), e0200019. https://doi.org/10.1371/journal.pone.0200019

561 Gonçalves, B., Esteves, P., Folgado, H., Ric, A., Torrents, C., & Sampaio, J. (2017). Effects of pitch area-
562   restrictions on tactical behavior, physical, and physiological performances in soccer large-sided games.
563   *The Journal of Strength & Conditioning Research*, *31*(9), 2398–2408.
564   https://doi.org/10.1519/JSC.0000000000001700

565 Gonçalves, B., Folgado, H., Coutinho, D., Marcelino, R., Wong, D., Leite, N., & Sampaio, J. (2018).
566   Changes in Effective Playing Space when Considering Sub-Groups of 3 to 10 Players in Professional
567   Soccer Matches. *Journal of Human Kinetics*, *62*, 145–155. https://doi.org/10.1515/hukin-2017-0166

568 Gonçalves, B., Marcelino, R., Torres-Ronda, L., Torrents, C., & Sampaio, J. (2016). Effects of emphasising
569   opposition and cooperation on collective movement behaviour during football small-sided games.
570   *Journal of Sports Sciences*, *34*(14), 1346–1354. https://doi.org/10.1080/02640414.2016.1143111

571 Gonçalves, B. V., Figueira, B. E., Maçãs, V., & Sampaio, J. (2014). Effect of player position on movement
572   behaviour, physical and physiological performances during an 11-a-side football game. *Journal of*
573   *Sports Sciences*, *32*(2), 191–199. https://doi.org/10.1080/02640414.2013.816761

574 Gore, C. (2000). *Physiological Tests for Elite Athletes*. Human Kinetics.

575 Goto, H., Morris, J. G., & Nevill, M. E. (2015). Motion analysis of U11 to U16 elite English Premier League
576   Academy players. *Journal of Sports Sciences*, *33*(12), 1248–1258.
577   https://doi.org/10.1080/02640414.2014.999700

578 Gréhaigne, J. F., Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationships in
579   collective actions in soccer. *Journal of Sports Sciences*, *15*(2), 137–149.
580   https://doi.org/10.1080/026404197367416

581 Harbourne, R. T., & Stergiou, N. (2009). Movement variability and the use of nonlinear tools: Principles
582   to guide physical therapist practice. *Physical Therapy*, *89*(3), 267–282.
583   https://doi.org/10.2522/ptj.20080130

584 Hewitt, A., Greenham, G., & Norton, K. (2016). Game style in soccer: What is it and can we quantify it?
585   *International Journal of Performance Analysis in Sport*, *16*, 355.
586   https://doi.org/10.1080/24748668.2016.11868892

587 Hill-Haas, S., Rowsell, G., Coutts, A., & Dawson, B. (2008). The reproducibility of physiological responses
588   and performance profiles of youth soccer players in small-sided games. *International Journal of Sports*
589   *Physiology and Performance*, *3*(3), 393–396. https://doi.org/10.1123/ijspp.3.3.393

590 Hodgson, C., Akenhead, R., & Thomas, K. (2014). Time-motion analysis of acceleration demands of 4v4
591   small-sided soccer games played on different pitch sizes. *Human Movement Science*, *33*, 25–32.
592   https://doi.org/10.1016/j.humov.2013.12.002

593 Hoppe, M. W., Baumgart, C., Polglaze, T., & Freiwald, J. (2018). Validity and reliability of GPS and LPS
594   for measuring distances covered and sprint mechanical properties in team sports. *PLOS ONE*, *13*(2),
595   e0192708. https://doi.org/10.1371/journal.pone.0192708

596 Hristovski, R., Davids, Araujo, D., Passos, P., Torrents, C., Aceski, A., & Tufekcievski. (2013). *Creativity*
597   *in sport and dance: Ecological dynamics on a hierarchically soft-assembled perception-action*
598   *landscape.* (pp. 259–271).

599 Jara, D., Ortega, E., Gómez-Ruano, M.-Á., Weigelt, M., Nikolic, B., & Sainz de Baranda, P. (2019).
600   Physical and Tactical Demands of the Goalkeeper in Football in Different Small-Sided Games.
601   *Sensors*, *19*(16), 3605. https://doi.org/10.3390/s19163605

602 Laakso, T., Davids, K., Luhtanen, P., Liukkonen, J., & Travassos, B. (2022). How football team
603   composition constrains emergent individual and collective tactical behaviours: Effects of player roles
604   in creating different landscapes for shared affordances in small-sided and conditioned games.
605   *International Journal of Sports Science & Coaching*, *17*(2), 346–354.
606   https://doi.org/10.1177/17479541211030076

607 Lames, M., Erdmann, J., & Walter, F. (2010). Oscillations in football—Order and disorder in spatial
608   interactions between the two teams. *International Journal of Sport Psychology*, *41*, 85–86.

609 Lee, K. A., Hicks, G., & Nino-Murcia, G. (1991). Validity and reliability of a scale to assess fatigue.
610   *Psychiatry Research*, *36*(3), 291–298. https://doi.org/10.1016/0165-1781(91)90027-m

611 Lefever, D. W. (1926). Measuring Geographic Concentration by Means of the Standard Deviational Ellipse.
612   *American Journal of Sociology*, *32*(1), 88–94. https://doi.org/10.1086/214027

613 Leser, R., Baca, A., & Ogris, G. (2011). Local Positioning Systems in (Game) Sports. *Sensors*, *11*(10),
614   9778–9797. https://doi.org/10.3390/s111009778

615 Linke, D., Link, D., & Lames, M. (2018). Validation of electronic performance and tracking systems EPTS
616   under field conditions. *PLOS ONE*, *13*(7), e0199519. https://doi.org/10.1371/journal.pone.0199519

617 Liu, H., Gómez, M.-A., Gonçalves, B., & Sampaio, J. (2016). Technical performance and match-to-match
618   variation in elite football teams. *Journal of Sports Sciences*, *34*(6), 509–518.
619   https://doi.org/10.1080/02640414.2015.1117121

620 Los Arcos, A., Martínez-Santos, R., Yanci, J., Martín, J., & Castagna, C. (2014). Variability of objective
621   and subjective intensities during ball drills in youth soccer players. *Journal of Strength and
622   Conditioning Research*, *28*(3), 752–757. https://doi.org/10.1519/JSC.0b013e3182a47f0b

623 Low, B., Coutinho, D., Gonçalves, B., Rein, R., Memmert, D., & Sampaio, J. (2019). A systematic review
624   of collective tactical behaviours in football using positional data. *Sports Medicine*, *50*, 1–43.
625   https://doi.org/10.1007/s40279-019-01194-7

626 Machado, J. C., Góes, A., Aquino, R., Bedo, B. L. S., Viana, R., Rossato, M., Scaglia, A., & Ibáñez, S. J.
627   (2022). Applying Different Strategies of Task Constraint Manipulation in Small-Sided and
628   Conditioned Games: How Do They Impact Physical and Tactical Demands? *Sensors*, *22*(12), 4435.
629   https://doi.org/10.3390/s22124435

630 Machado, J., Barreira, D., Teoldo, I., Serra-Olivares, J., Góes, A., & José Scaglia, A. (2020). Tactical
631   Behaviour of Youth Soccer Players: Differences Depending on Task Constraint Modification, Age and
632   Skill Level. *Journal of Human Kinetics*, *75*, 225–238. https://doi.org/10.2478/hukin-2020-0051

633 Mallo, J., Mena, E., Nevado, F., & Paredes, V. (2015). Physical Demands of Top-Class Soccer Friendly
634   Matches in Relation to a Playing Position Using Global Positioning System Technology. *Journal of
635   Human Kinetics*, *47*, 179–188. https://doi.org/10.1515/hukin-2015-0073

636 Malone, J. J., Jaspers, A., Helsen, W., Merks, B., Frencken, W. G. P., & Brink, M. S. (2018). Seasonal
637   Training Load and Wellness Monitoring in a Professional Soccer Goalkeeper. *International Journal
638   of Sports Physiology and Performance*, *13*(5), 672–675. https://doi.org/10.1123/ijspp.2017-0472

639 Marcelino, R., Sampaio, J., Amichay, G., Gonçalves, B., Couzin, I. D., & Nagy, M. (2020). Collective
640   movement analysis reveals coordination tactics of team players in football matches. *Chaos, Solitons
641   & Fractals*, *138*, 109831. https://doi.org/10.1016/j.chaos.2020.109831

642 McGarry, T., Anderson, D. I., Wallace, S. A., Hughes, M. D., & Franks, I. M. (2002). Sport competition as
643   a dynamical self-organizing system. *Journal of Sports Sciences*, *20*(10), 771–781.
644   https://doi.org/10.1080/026404102320675620

645 Memmert, D. (2021). *Match Analysis: How to Use Data in Professional Sport*. Routledge.

646 Memmert, D., Lemmink, K. A. P. M., & Sampaio, J. (2017). Current approaches to tactical performance
647   analyses in soccer using position data. *Sports Medicine*, *47*(1), 1–10. https://doi.org/10.1007/s40279-
648   016-0562-5

649 Mendes, R. S., Malacarne, L. C., & Anteneodo, C. (2007). Statistics of football dynamics. *The European*
650   *Physical Journal B*, *57*(3), 357–363. https://doi.org/10.1140/epjb/e2007-00177-4

651 Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic
652   reviews and meta-analyses: The PRISMA statement. *BMJ*, *339*. https://doi.org/10.1136/bmj.b2535

653 Nieto, S., Castellano, J., Echeazarra, I., & Fernández, E. (2022). Effects on collective behaviour and
654   locomotor and neuromuscular response in young players by varying the length of the pitch in 11-a-
655   side football. *International Journal of Sports Science & Coaching*, 17479541221101604.
656   https://doi.org/10.1177/17479541221101603

657 O'Donoghue, P. (2009). *Research methods for sports performance analysis*. Routledge.
658   https://doi.org/10.4324/9780203878309

659 Ogris, G., Leser, R., Horsak, B., Kornfeind, P., Heller, M., & Baca, A. (2012). Accuracy of the LPM
660   tracking system considering dynamic position changes. *Journal of Sports Sciences*, *30*(14), 1503–
661   1511. https://doi.org/10.1080/02640414.2012.712712

662 Olthof, S. B. H., Frencken, W. G. P., & Lemmink, K. A. P. M. (2018). Match-derived relative pitch area
663   changes the physical and team tactical performance of elite soccer players in small-sided soccer games.
664   *Journal of Sports Sciences*, *36*(14), 1557–1563. https://doi.org/10.1080/02640414.2017.1403412

665 Ometto, L., Vasconcellos, F. V., Cunha, F. A., Teoldo, I., Souza, C. R. B., Dutra, M. B., O'Sullivan, M., &
666   Davids, K. (2018). How manipulating task constraints in small-sided and conditioned games shapes
667   emergence of individual and collective tactical behaviours in football: A systematic review.
668   *International Journal of Sports Science & Coaching*, *13*(6), 1200–1214.
669   https://doi.org/10.1177/1747954118769183

670 Palut, Y., & Zanone, P.-G. (2005). A dynamical analysis of tennis: Concepts and data. *Journal of Sports*
671   *Sciences*, *23*(10), 1021–1032. https://doi.org/10.1080/02640410400021682

672 Paul, D. J., Bradley, P. S., & Nassis, G. P. (2015). Factors affecting match running performance of elite
673   soccer players: Shedding some light on the complexity. *International Journal of Sports Physiology*
674   *and Performance*, *10*(4), 516–519. https://doi.org/10.1123/IJSPP.2015-0029

675 Pincus, S. M. (1991). Approximate entropy as a measure of system complexity. *Proceedings of the National*
676   *Academy of Sciences*, *88*(6), 2297–2301. https://doi.org/10.1073/pnas.88.6.2297

677 Pol, R., Balagué, N., Ric, A., Torrents, C., Kiely, J., & Hristovski, R. (2020). Training or synergizing?
678   Complex systems principles change the understanding of sport processes. *Sports Medicine - Open*,
679   *6*(1), 28. https://doi.org/10.1186/s40798-020-00256-9

680 Portas, M. D., Harley, J. A., Barnes, C. A., & Rush, C. J. (2010). The validity and reliability of 1-Hz and
681   5-Hz global positioning systems for linear, multidirectional, and soccer-specific activities.
682   *International Journal of Sports Physiology and Performance*, *5*(4), 448–458.
683   https://doi.org/10.1123/ijspp.5.4.448

684 Praça, G. M., Andrade, A. G. P., Bredt, S. da G. T., Moura, F. A., & Moreira, P. E. D. (2020). Progression
685   to the target vs. Regular rules in Soccer small-sided Games. *Science and Medicine in Football*, *0*(0),
686   1–6. https://doi.org/10.1080/24733938.2020.1869811

687 Praça, G. M., Folgado, H., Andrade, A. G. P. de, & Greco, P. J. (2016). Influence of additional players on
688   collective tactical behavior in small-sided soccer games. *Revista Brasileira de Cineantropometria &*
689   *Desempenho Humano*, *18*, 62–71. https://doi.org/10.5007/1980-0037.2016v18n1p62

690 Praça, G. M., Moreira, P. E. D., Dieguez, G. T. de O., Barbosa, T. de O., Brandão, L. H. A., & Custódio, I.
691   J. de O. (2021). The impact of match venue on performance indicators and tactical behaviour in youth
692   soccer players. *International Journal of Performance Analysis in Sport*, *0*(0), 1–11.
693   https://doi.org/10.1080/24748668.2021.1952831

694 Preatoni, E., Ferrario, M., Donà, G., Hamill, J., & Rodano, R. (2010). Motor variability in sports: A non-
695   linear analysis of race walking. *Journal of Sports Sciences*, *28*(12), 1327–1336.
696   https://doi.org/10.1080/02640414.2010.507250

697 Preciado, M., Anguera, M. T., Olarte, M., & Lapresa, D. (2019). Observational Studies in Male Elite
698   Football: A Systematic Mixed Study Review. *Frontiers in Psychology*, *10*.
699   https://doi.org/10.3389/fpsyg.2019.02077

700 Rago, V., Brito, J., Figueiredo, P., Costa, J., Barreira, D., Krustrup, P., & Rebelo, A. (2020). Methods to
701   collect and interpret external training load using microtechnology incorporating GPS in professional
702   football: A systematic review. *Research in Sports Medicine*, *28*(3), 437–458.
703   https://doi.org/10.1080/15438627.2019.1686703

704 Rampinini, E., Impellizzeri, F. M., Castagna, C., Coutts, A. J., & Wisløff, U. (2009). Technical performance
705   during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *Journal
706   of Science and Medicine in Sport*, *12*(1), 227–233. https://doi.org/10.1016/j.jsams.2007.10.002

707 Ranjitha, M., Nathan, K., & Joseph, L. (2020). Artificial Intelligence Algorithms and Techniques in the
708   computation of Player-Adaptive Games. *Journal of Physics: Conference Series*, *1427*(1), 012006.
709   https://doi.org/10.1088/1742-6596/1427/1/012006

710 Rein, R., & Memmert, D. (2016). Big data and tactical analysis in elite soccer: Future challenges and
711   opportunities for sports science. *SpringerPlus*, *5*(1), 1410. https://doi.org/10.1186/s40064-016-3108-
712   2

713 Reis, M. A. M. D., & Almeida, M. B. (2020). The role of somatic maturation in the tactical effectiveness,
714   efficiency and variability of young soccer players. *International Journal of Performance Analysis in
715   Sport*, *20*(2), 305–321. https://doi.org/10.1080/24748668.2020.1743165

716 Ric, A., Hristovski, R., Gonçalves, B., Torres, L., Sampaio, J., & Torrents, C. (2016). Timescales for
717   exploratory tactical behaviour in football small-sided games. *Journal of Sports Sciences*, *34*(18), 1723–
718   1730. https://doi.org/10.1080/02640414.2015.1136068

719 Ric, A., Torrents, C., Gonçalves, B., Sampaio, J., & Hristovski, R. (2016). Soft-assembled Multilevel
720   Dynamics of Tactical Behaviors in Soccer. *Frontiers in Psychology*, *0*.
721   https://doi.org/10.3389/fpsyg.2016.01513

722 Ric, A., Torrents, C., Gonçalves, B., Torres-Ronda, L., Sampaio, J., & Hristovski, R. (2017). Dynamics of
723   tactical behaviour in association football when manipulating players' space of interaction. *PLOS ONE*,
724   *12*(7), e0180773. https://doi.org/10.1371/journal.pone.0180773

725 Richman, J. S., & Moorman, J. R. (2000). Physiological time-series analysis using approximate entropy
726   and sample entropy. *American Journal of Physiology-Heart and Circulatory Physiology*, *278*(6),
727   H2039–H2049. https://doi.org/10.1152/ajpheart.2000.278.6.H2039

728 Rico-González, M., Los Arcos, A., Nakamura, F. Y., Gantois, P., & Pino-Ortega, J. (2020). A comparison
729   between UWB and GPS devices in the measurement of external load and collective tactical behaviour
730   variables during a professional official match. *International Journal of Performance Analysis in Sport*,
731   *20*(6), 994–1002. https://doi.org/10.1080/24748668.2020.1823153

732 Rico-González, M., Pino-Ortega, J., Castellano, J., Oliva-Lozano, J. M., & Arcos, A. L. (2021). Reference
733   values for collective tactical behaviours based on positional data in professional football matches: A
734   systematic review. *Biology of Sport*, *39*(1), 101–114. https://doi.org/10.5114/biolsport.2021.102921

735 Rojas-Valverde, D., Gómez-Carmona, C. D., Gutiérrez-Vargas, R., & Pino-Ortega, J. (2019). From big data
736   mining to technical sport reports: The case of inertial measurement units. *BMJ Open Sport & Exercise*
737   *Medicine*, 5(1), e000565. https://doi.org/10.1136/bmjsem-2019-000565

738 Russell, M., Sparkes, W., Northeast, J., Cook, C. J., Love, T. D., Bracken, R. M., & Kilduff, L. P. (2016).
739   Changes in Acceleration and Deceleration Capacity Throughout Professional Soccer Match-Play. *The*
740   *Journal of Strength & Conditioning Research*, 30(10), 2839–2844.
741   https://doi.org/10.1519/JSC.0000000000000805

742 Sampaio, J. E., Lago, C., Gonçalves, B., Maçãs, V. M., & Leite, N. (2014). Effects of pacing, status and
743   unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football
744   small-sided games. *Journal of Science and Medicine in Sport*, 17(2), 229–233.
745   https://doi.org/10.1016/j.jsams.2013.04.005

746 Sampaio, J., & Vitor, M. (2012). Measuring Tactical Behaviour in Football. *International Journal of Sports*
747   *Medicine*, 33, 395–401. https://doi.org/10.1055/s-0031-1301320

748 Santos, S., Coutinho, D., Gonçalves, B., Schöllhorn, W., Sampaio, J., & Leite, N. (2018). Differential
749   Learning as a Key Training Approach to Improve Creative and Tactical Behavior in Soccer. *Research*
750   *Quarterly for Exercise and Sport*, 89, 1–14. https://doi.org/10.1080/02701367.2017.1412063

751 Sarmento, H., Clemente, F. M., Araújo, D., Davids, K., McRobert, A., & Figueiredo, A. (2018). What
752   Performance Analysts Need to Know About Research Trends in Association Football (2012–2016): A
753   Systematic Review. *Sports Medicine*, 48(4), 799–836. https://doi.org/10.1007/s40279-017-0836-6

754 Saxton, M. J. (1996). Anomalous diffusion due to binding: A Monte Carlo study. *Biophysical Journal*,
755   70(3), 1250–1262. https://doi.org/10.1016/S0006-3495(96)79682-0

756 Seifert, L., Button, C., & Davids, K. (2013). Key properties of expert movement systems in sport: An
757   ecological dynamics perspective. *Sports Medicine (Auckland, N.Z.)*, 43(3), 167–178.
758   https://doi.org/10.1007/s40279-012-0011-z

759 Silva, P., Chung, D., Carvalho, T., Cardoso, T., Davids, K., Araújo, D., & Garganta, J. (2016). Practice
760   effects on intra-team synergies in football teams. *Human Movement Science*, 46, 39–51.
761   https://doi.org/10.1016/j.humov.2015.11.017

762 Silva, P., Duarte, R., Esteves, P., Travassos, B., & Vilar, L. (2016). Application of entropy measures to
763   analysis of performance in team sports. *International Journal of Performance Analysis in Sport*, 16(2),
764   753–768. https://doi.org/10.1080/24748668.2016.11868921

765 Silva, P., Vilar, L., Davids, K., Araújo, D., & Garganta, J. (2016). Sports teams as complex adaptive
766   systems: Manipulating player numbers shapes behaviours during football small-sided games.
767   *SpringerPlus*, 5(1), 191. https://doi.org/10.1186/s40064-016-1813-5

768 Stagno, K. M., Thatcher, R., & van Someren, K. A. (2007). A modified TRIMP to quantify the in-season
769   training load of team sport players. *Journal of Sports Sciences*, 25(6), 629–634.
770   https://doi.org/10.1080/02640410600811817

771 Stergiou, N., Buzzi, U., Kurz, M., & Heidel, J. (2004). *Nonlinear tools in human movement.* Champaign,
772   IL , Human Kinetics.

773 Synnot, A., Tong, A., Ryan, R., & Hill, S. (2020). Evaluation of the Cochrane Consumers and
774   Communication Group's systematic review priority-setting project. Health Research Policy and
775   Systems, 18(1), 98. https://doi.org/10.1186/s12961-020-00604-x

776 Teixeira, J. E., Alves, A. R., Ferraz, R., Forte, P., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., &
777   Monteiro, A. M. (2022). Effects of chronological age, relative age, and maturation status on

778   accumulated training load and perceived exertion in young sub-elite football players. *Frontiers in*
779   *Physiology*, *13*, 832202.

780 Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M.
781   (2021a). Monitoring accumulated training and match load in football: A systematic review.
782   *International Journal of Environmental Research and Public Health*, *18*(8), 3906.
783   https://doi.org/10.3390/ijerph18083906

784 Teixeira, J. E., Forte, P., Ferraz, R., Leal, M., Ribeiro, J., Silva, A. J., Barbosa, T. M., & Monteiro, A. M.
785   (2021b). Quantifying sub-elite youth football weekly training load and recovery variation. *Applied*
786   *Sciences*, *11*(11), 4871. https://doi.org/10.3390/app11114871

787 Teixeira, J. E., Leal, M., Ferraz, R., Ribeiro, J., Cachada, J. M., Barbosa, T. M., Monteiro, A. M., & Forte,
788   P. (2021). Effects of match location, quality of opposition and match outcome on match running
789   performance in a Portuguese professional football team. *Entropy*, *23*(8), 973.
790   https://doi.org/10.3390/e23080973

791 Teixeira, J., Forte, P., Ferraz, R., Branquinho, L., Silva, A., Barbosa, T., & Monteiro, A. (2022).
792   *Methodological Procedures for Non-Linear Analyses of Physiological and Behavioural Data in*
793   *Football*. https://doi.org/10.5772/intechopen.102577

794 Travassos, B., Araújo, D., Vilar, L., & McGarry, T. (2011). Interpersonal coordination and ball dynamics
795   in futsal (indoor football). *Human Movement Science*, *30*(6), 1245–1259.
796   https://doi.org/10.1016/j.humov.2011.04.003

797 Travassos, B., Davids, Araujo, D., & Esteves, P. (2013). Performance analysis in team sports: Advances
798   from an ecological dynamics approach. *International Journal of Performance Analysis in Sport*, *13*,
799   89–95. https://doi.org/10.1080/24748668.2013.11868633

800 Travassos, B., Gonçalves, B., Marcelino, R., Monteiro, R., & Sampaio, J. (2014). How perceiving
801   additional targets modifies teams' tactical behavior during football small-sided games. *Human*
802   *Movement Science*, *38*, 241–250. https://doi.org/10.1016/j.humov.2014.10.005

803 Vidal-Codina, F., Evans, N., Fakir, B. E., & Billingham, J. (2022). *Automatic event detection in football*
804   *using tracking data* (arXiv:2202.00804). arXiv. https://doi.org/10.48550/arXiv.2202.00804

805 Vilar, L., Araújo, D., Davids, K., Travassos, B., Duarte, R., & Parreira, J. (2014). Interpersonal coordination
806   tendencies supporting the creation/prevention of goal scoring opportunities in futsal. *European*
807   *Journal of Sport Science*, *14*(1), 28–35. https://doi.org/10.1080/17461391.2012.725103

808 Welsh, A. H., & Knight, E. J. (2015). "Magnitude-based Inference": A Statistical Review. *Medicine and*
809   *Science in Sports and Exercise*, *47*(4), 874–884. https://doi.org/10.1249/MSS.0000000000000451

810 Wisbey, B., Montgomery, P. G., Pyne, D. B., & Rattray, B. (2010). Quantifying movement demands of
811   AFL football using GPS tracking. *Journal of Science and Medicine in Sport*, *13*(5), 531–536.
812   https://doi.org/10.1016/j.jsams.2009.09.002

813 Yentes, J. M., Hunt, N., Schmid, K. K., Kaipust, J. P., McGrath, D., & Stergiou, N. (2013). The appropriate
814   use of approximate entropy and sample entropy with short data sets. *Annals of Biomedical*
815   *Engineering*, *41*(2), 349–365. https://doi.org/10.1007/s10439-012-0668-3

816 Yuill, R. S. (1971). The Standard Deviational Ellipse; An Updated Tool for Spatial Description.
817   *Geografiska Annaler: Series B, Human Geography*, *53*(1), 28–39.
818   https://doi.org/10.1080/04353684.1971.11879353

1   **Title page**

2   **Manuscript Title:**

3   Integrating physical, physiological and tactical factors in football using positional data: A

4   Systematic Review.

5   **Running heading:**

6   Physical, physiological and tactical factors using positional data (Football).

7   **Authors:** José E. Teixeira[1,2*], Pedro Forte[1,2,4], Ricardo Ferraz[1,4], Luís Branquinho[4], António J.

8   Silva[1,5], António M. Monteiro[1,3] and Tiago M. Barbosa[1,3]

9   [1] Research Centre in Sports Sciences, Health and Human Development, 5001-801 Vila Real, Portugal

10   [2] Departamento de Desporto e Educação Física, Instituto Politécnico de Bragança, 5300-253 Bragança, Portugal;

11   jose.eduardo@ipb.pt (J.E.T.); barbosa@ipb.pt (T.M.B.); mmonteiro@ipb.pt (A.M.M.)

12   [3] Department of Sports, Douro Higher Institute of Educational Sciences, 4560-708 Penafiel, Portugal;

13   pedromiguel.forte@iscedouro.pt (P.F.); luis.branquinho@iscedouro.pt (L.B.)

14   [4] Department of Sports Sciences, University of Beira Interior, 6201-001 Covilhã, Portugal; rmpf@ubi.pt (R.F.)

15   [5] Department of Sports, Exercise and Health Sciences, University of Trás-os-Montes e Alto Douro, 5001-801 Vila Real, Portugal;

16   ajsilva@utad.pt (A.J.S.)

17   **Corresponding author:**

18   **E-mail:** **barbosa@ipb.pt** **(T.M.B.)**

     ORCID: 0000-0001-7071-2116

19   **Word count (*Abstract*):** 308 words.

20   **Word count (*Text, including tables & figures*):** 9181 words.

21   **Word count (*Text, excluding tables & figures*):** 4213 words.

22   **Number of tables:** 5 (five).

23   **Number of figures:** 1 (one).

24 **Declarations**

25 **Funding:** This research was supported by Portuguese Foundation for Science and Technology,

26 I.P. (project UIDB04045/2021).

27 **Author contributions:** Conceptualization, J.E.T. and P.F.; Data curation, J.E.T., R.F. and P.F.;

28 Formal analysis, P.F., R.F., and L.B.; Funding acquisition, T.M.B.; Investigation, J.E.T., L.B.;

29 Methodology, P.F., L.B. and T.M.B.; Resources, P.F. and A.M.M.; Software, J.E.T., L.B. and

30 R.F.; Supervision, A.J.S. and A.M.M.; Validation, P.F., T.M.B. and R.F.; Writing – original draft,

31 J.E.T.; Writing – review & editing, P.F., R.F., L.B., A.J.S., T.M.B. and A.M.M. All authors have

32 read and agreed to the published version of the manuscript.

33 **Conflicts of Interest:** The authors declare no potential conflict of interest.

34 **Acknowledgements:** The authors express acknowledgement to the authors who provided

35 additional information for the studies included in this systematic review.
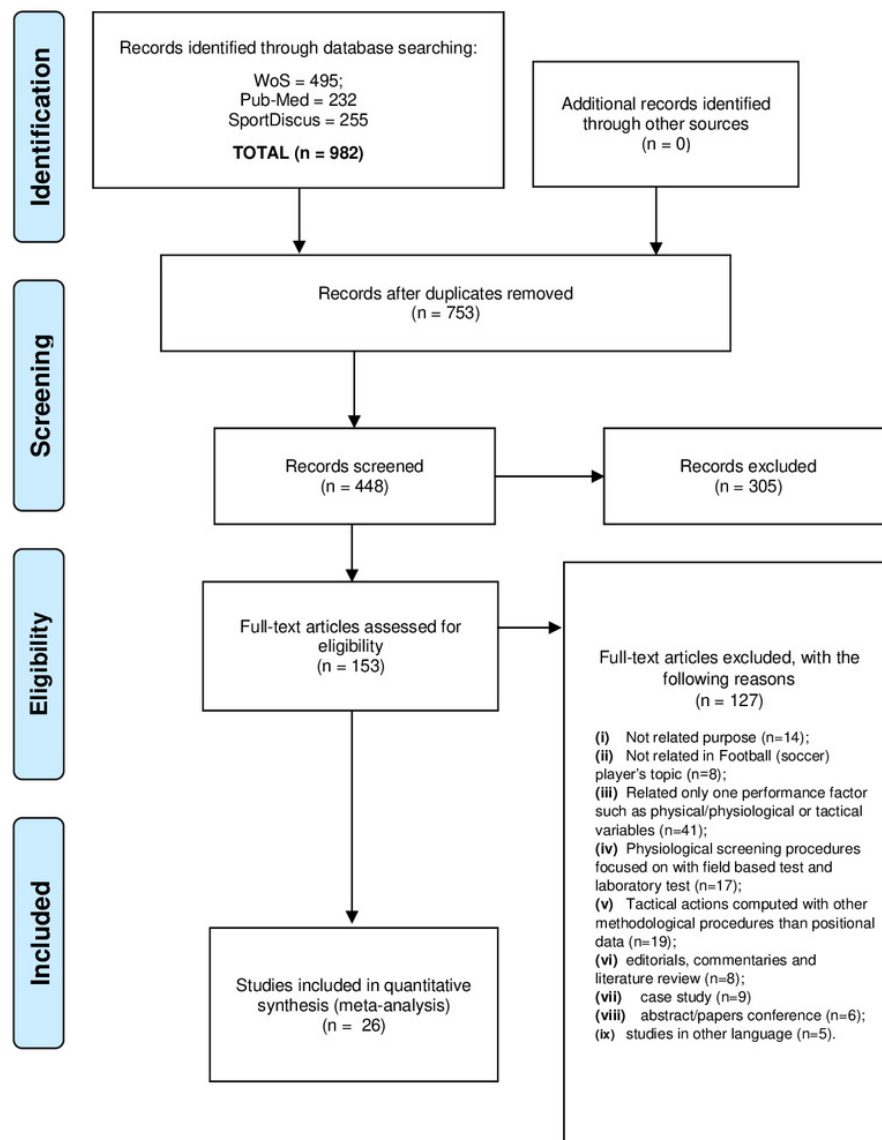
Figure 1

PRISMA flow diagram

Figure 1 – PRISMA flow diagram

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**	**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" **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"
Boolean phrase	**4**	(((#4) AND #3) AND #2) AND #1

Search results in each databases according to keywords organized by PICOS approach

Table 1 – Search results in each databases according to keywords organized by PICOS approach.

	Keywords	WoS	Pubmed	SportDiscus
1	**Population**	4,676,382	23,271	13,601
2	**Intervention**	49,393	1,599,092	1,933,970
3	**Physiological set:**	3,110,696	4,859,719	2,252,599
	Positional data	6,950,422	2,305,115	2,948,550
4	(((#4) AND #3) AND #2) AND #1	495	232	255

Abbreviations: PICOS – 'Population-Intervention-Comparators-Outcomes' approach.

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

Table 3 – 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)	QS
Baptista et al. (2020)	RCT	Adult, Semiprofessional	23	Male	24.9 ± 6.5	12.6 ± 5.5	4
Canton et al. (2021)	RCT	Youth, High-Level	24	Male	**U12:** 11.3 ± 0.8	**U12:** 3.13 ± 1.5	5
Coutinho et al. (2017)	RCT	Youth, Amateur	12	Male	15.9 ± 0.8	8.9 ± 2.4	5
Coutinho et al. (2019)	RCT	Youth, Amateur	12	Male	15.9 ± 0.8	8.9 ± 2.4	5
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	6
Coutinho et al. (2020)	RCT	Youth, ND	10	Male	13.7 ± 0.5	6.1 ± 0.9	5
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	5
Coutinho et al. (2022)	RCT	Youth, Regional Level	20	Male	16.1 ± 0.9	7.5 ± 3.4	6
Coutinho et al. (2022)	RCT	Youth, ND	21	Male	16.2 ± 0.6	8.3 ± 2.8	7
Ferraz et al. (2020)	RCT	Adult, Professional	20	Male	22.3 ± 2.1	10.3 ± 3.4	6
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	3
Folgado et al. (2015)	Observational cohort	Adult, Professional	23	Male	25.5±3.6	9.0 ± 3.7	5
Folgado et al. (2018)	Observational cohort	Adult, Professional	30	Male	23.7 ± 4.2	4.8 ± 4.2	5
Folgado et al. (2019)	RCT	Youth, National Level	20	Male	**U15:** 14.1 ± 0.5	**U15:** 6.4 ± 1.8	6
Gonçalves et al. (2014)	Observational cohort	Youth, Elite	22	Male	18.1 ± 0.7	9.4 ± 1.3	4
Gonçalves et al. (2017)	RCT	Adult, Professional	19	Male	25.1 ± 4.1	18.8 ± 5.3	5
Gonçalves et al. (2018)	Observational cohort	Adult, Professional	28	Male	24.7 ± 4.7	6.5 ± 4.7	6
Jara et al. (2019)	RCT	Adult, Elite	3	Male	24.7 ± 7.2	11.0 ± 4.7	4
Machado et al. (2022)	RCT	Youth, Recreational	10	Male	16.89 ± 0.11	ND	4
Nieto et al. (2022)	RCT	Youth, Elite	22	Male	14.6 ± 0.3	5.5 ± 0.5	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	6
Praça et al. (2016)	Observational cohort	Youth, National Level	18	Male	16.4 ± 0.7	4.2 ± 0.0	3
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	4
Ric et al. (2016)	RCT	Adult, Professional	8	Male	26 ± 4.96	19.6 ± 4.9	5
Ric et al. (2017)	RCT	Adult, Professional	21	Male	25.1 ± 4.1	18.8 ± 5.3	5
Sampaio et al. (2014)	Observational cohort	Adult, volunteer	24	Male	20.8 ± 1.0	5.2 ± 1.3	4
All studies	-	-	**764**	-	**16.81 ± 1.63**	**4.2 ± 3.83**	**4.92**

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

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

1   **Table 4** – 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/Physiological data	External load	Movement speed	TD (m)	Distance covered at high to very high (Higher Ratio: above 16 km·h⁻¹), moderate (Moderate Ratio: 10.0–15.9 km·h⁻¹) and low intensity (Lower Ratio: 7.0–9.9 km·h⁻¹) with distance covered at very low intensities (0.0–6.9 km·h⁻¹)	(Canton et al., 2021; Coutinho, Gonçalves, Santos, et al., 2019; Coutinho, Gonçalves, Travassos, et al., 2019)	(Abade et al., 2014; P. S. Bradley & Ade, 2018; Hodgson et al., 2014)

Dimension	Measure	Measurement	Description, thresholds and/or metric formula	Reference	Further reading
Physical/Physiological data	External load	Movement speed	TD (m)	Distance covered at high to very high (Higher Ratio: above 16 km·h⁻¹), moderate (Moderate Ratio: 10.0–15.9 km·h⁻¹) and low intensity (Lower Ratio: 7.0–9.9 km·h⁻¹) with distance covered at very low intensities (0.0–6.9 km·h⁻¹)	(Canton et al., 2021; Coutinho, Gonçalves, Santos, et al., 2019; Coutinho, Gonçalves, Travassos, et al., 2019)	(Abade et al., 2014; P. S. Bradley & Ade, 2018; Hodgson et al., 2014)
				0.0–3.5 km·h⁻¹ (walking); 3.6–14.3 km·h⁻¹ (jogging); 14.4–19.7 km·h⁻¹ (running); and >19.8 km·h⁻¹ (sprinting)	(Coutts & Duffield, 2010; Ferraz et al., 2020; Figueira et al., 2018; Folgado et al., 2015, 2018; B. Gonçalves et al., 2017; B. Gonçalves, Coutinho, et al., 2018; Ric, Hristovski, et al., 2016; Ric et al., 2017)	(Duarte, Araújo, Folgado, et al., 2013; Folgado, Duarte, et al., 2014; Giménez et al., 2018; B. Gonçalves et al., 2017)
				Zone 1 (0–6.9 km·h⁻¹); zone 2 (7–9.9 km·h⁻¹); zone 3 (10–12.9 km·h⁻¹); zone 4 (13–15.9 km·h⁻¹); zone 5 (16–17.9 km·h⁻¹) and zone 6 (≥18 km·h⁻¹).	(Sampaio et al., 2014)	(Hill-Haas et al., 2008)
			High Speed (km·h⁻¹)	(distance covered in the high ratio/distance covered while walking)*100	(Coutinho, Gonçalves, Santos, et al., 2019; Coutinho, Gonçalves, Travassos, et al., 2019)	(Abade et al., 2014; B. Gonçalves, Folgado, et al., 2018)
				Distance covered at high intensity (≥ 19.8 km·h⁻¹) and number of sprints (frequency of displacements ≥ 25.2 km·h⁻¹)	(Olthof et al., 2018)	(Abt & Lovell, 2009; Goto et al., 2015)
				Distance covered at high-speed at three speed zones (14.40–19.79 km·h⁻¹, 19.80–22.99 km·h⁻¹, higher than 23.00 km·h⁻¹) and number of sprints (frequency of displacements ≥ 23.00 km·h⁻¹)	(Praça et al., 2021)	(Mallo et al., 2015; Praça et al., 2020)
			Game Pace or Average Speed (km·h⁻¹ *or* CV)	Players' average speed displacement, expressed as meters or CV.	(Canton et al., 2021; Coutinho, Gonçalves, Santos, et al., 2019; Coutinho, Gonçalves, Travassos, et al., 2019)	(Ferraz et al., 2017, 2018; B. Gonçalves et al., 2019)
			ACC/DEC (m·s⁻²)	ACC: 0.5-3.0 m·s⁻²; DEC: > -3.0 0 m·s⁻²	(Coutinho et al., 2017)	(Dalen et al., 2016; Russell et al., 2016)
	Internal load	Heart Rate	HR$_{max}$	Percentage of HR$_{max}$ and classified into time spend in following zones of intensity: 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; J. E. Sampaio et al., 2014)	(Abt & Lovell, 2009; Gore, 2000)
			Average HR	Average beats per minute (BPM)	(B. Gonçalves et al., 2017)	ND
			TRIMP$_{MOD}$	Total TRIMP$_{MOD}$ result is equal to the sum of all HR zones: 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)
Positional data	Spatial and temporal features	Spatial movement variability/regularity	CV	Magnitude of the variability in the distance between players', expressed by the coefficient of variation CV (%)	(Coutinho, Gonçalves, Travassos, et al., 2019; Coutinho et al., 2020; Figueira et al., 2018; B. Gonçalves et al., 2017)	(Frencken et al., 2012; Harbourne & Stergiou, 2009; Seifert et al., 2013; Travassos et al., 2014)
			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*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, Araújo, Davids, et al., 2012; B. 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 total number of the configuration respectively.	(Ric, Hristovski, et al., 2016)	(Balescu, 1975)
			MSE SamEn	SampEn algorithm to compute entropy values at a range of different timescales, calculating the area under the MSE curves were calculated and presented as the complexity index.	(Canton et al., 2021)	(Busa & van Emmerik, 2016; M. Costa et al., 2005)
		Complex Index	SEI	Width and length displacements. Distance from each positioning time series to the mean position and then computing the mean value from all the obtained distances.	(Canton et al., 2021; Figueira et al., 2018; B. Gonçalves et al., 2017; Praça et al., 2021)	(Arede et al., 2021; F. M. Clemente, Owen, Mustapha, et al., 2018; F. M. Clemente, Owen, Serra-Olivares, et al., 2018; Travassos et al., 2014)

			Description		
		Stretch Index (meters or ApEn)	Men of the distances between each player and the geometric centre of the team.	(Coutinho, Gonçalves, Travassos, et al., 2019; Olthof et al., 2018; Praça et al., 2021)	(Bourbousson et al., 2010; F. M. Clemente et al., 2013; F. M. Clemente, Owen, Serra-Olivares, et al., 2018; Duarte, Araújo, Folgado, et al., 2013; Lames et al., 2010; Travassos et al., 2014)
		Dynamic overlap <qd(t)>	Average cosine auto-similarity of the overlap between configurations with increasing time lag: $$< q_d(t) > \; = (1 - q_{stat})t^\alpha + q_{stat}$$	(Ric, Hristovski, 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. The larger (lower) the trapping strength, the smaller (larger) is the overall behavioural flexibility.		
		Voronoi algoritms	Voronoi algorithms allow to compute a diagram represented by spatial cells for individual area (m²), among each one associated with the position of one player in the field.	(Baptista et al., 2020)	(Fonseca et al., 2012)
	Coordination/synchronization using intra-team dyads	Relative phase (Hilbert transform)	Longitudinal and lateral directions reported using near-inphase synchronization of each dyad was quantified by the percentage of time spent between −30º to 30º bin (near-in-phase mode of coordination).	(Coutinho et al., 2020; Coutinho, Gonçalves, Santos, et al., 2019; Fernandes et al., 2010; Figueira et al., 2018; Folgado et al., 2015, 2019; B. Gonçalves, Coutinho, et al., 2018; B. Gonçalves et al., 2017)	(Duarte, Araújo, Freire, et al., 2012; Duarte, Araújo, Davids, et al., 2012; Duarte, Araújo, Correia, et al., 2013; Folgado, Duarte, et al., 2014; Folgado, Lemmink, et al., 2014a; B. Gonçalves et al., 2019; McGarry et al., 2002; Palut & Zanone, 2005; J. Sampaio & Vitor, 2012; Silva, Chung, 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; B. Gonçalves, Coutinho, et al., 2018)	(Folgado, Duarte, et al., 2014; Folgado, Lemmink, et al., 2014a)
	Coordination/synchronization using inter-team dyads	Distance Player–Teammate / Distance Player–Opponent	Interpersonal distance between each pair of players, both with teammates and opponents: $$D\,(a_{x_{(t)},y_{(t)}}, b_{x_{(t)},y_{(t)}}) = \sqrt{(a_{x_{(t)},y_{(t)}})^2 + (a_{x_{(t)},y_{(t)}})^2}$$ 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; J. E. Sampaio et al., 2014)	(B. V. Gonçalves et al., 2014; Low et al., 2020; Silva, Vilar, et al., 2016)
	Playing Space	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 (m²)	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, Araújo, Folgado, et al., 2013; Folgado, Lemmink, et al., 2014a; Mendes et al., 2007; Ric, Torrents, et al., 2016; Russell et al., 2016; J. 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 $100(1 - \alpha)$ % of the observations or set of points. $$\bar{x} = \frac{1}{n}\sum_{i=0}^{n} x_i, \bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$	(Jara et al., 2019)	(Batshcelet, 1981; Lefever, 1926; Yuill, 1971)
		Team's width and length / Team's speed contraction dispersion / Team centroid	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; B. Gonçalves et al., 2017; Praça et al., 2021)	(Duarte, Araújo, Folgado, et al., 2013; Folgado, Lemmink, et al., 2014a; Frencken et al., 2011; Mendes et al., 2007; Ric, Torrents, et al., 2016)
Other dimensions	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 while dribbling; number of completed passes; completed passes distance; shots distance to the goal; distance between the attacker the closest defender when shooting.	(Folgado et al., 2019; Olthof et al., 2018)	(Rampinini et al., 2009)
			The total passes performed with successful reception by a teammate, as well as turnovers (losing possession of the ball), goals scored and relative frequencies of players' passing interactions.	(Ric et al., 2017)	(M. Costa et al., 2005)

			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.		
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; I. T. da Costa et al., 2011; Gabin et al., 2012)
	Network	Dyad Nodes	Relative phase analysis was also divided according to each dyad average speed, using the previously presented movement speed categories. 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 tens categories: 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.)	Players' psychological states at the beginning and the final of both conditions using CR10-scale (0 to 10 arbitrary units).	(Coutinho et al., 2017)	(Lee et al., 1991)
		Exertion index	Wisbey's formula: players' instantaneous speed, speed over 10 s and speed over 60 s.	(Folgado et al., 2015)	(Wisbey et al., 2010)

Abbreviations: <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.

3

Methodological approaches of included articles

1 Table 5 – Methodological approaches of included articles.

Referente (year)	Study Purpose	Match-play	Training set	Game format	Physical/ Physiological	Positional/ Tactical	Other dimensions	Methodological procedures	Data Collection (Device specification)	Statistical and mathematical analysis
					Experimental Approach					
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' *d* SWC MBI ApEn Voronoi algorithme
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' *d* 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' *d* 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' *d* 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' *d* 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' *d* 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' *d* 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' *d*
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 (MinimaxX S5, Catapult Innovations, Australia). Digital Video Camera (Canon PowerShot SX720 HS, Canon Inc,	ICC SEM Cohen' *d* 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' d 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' d 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' d 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, Almería, Spain)	10 Hz GPS and inertial devices (WIMU ProTM and GPS, RealTrack System, Almería, 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' d 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). LPM system (Inmotio Object Tracking BV., Amsterdam, the Netherlands)	NHST Effect sized eta-squared (η_p^2)
Praça et al. (2016)	Compared the collective tactical behavior between numerically balanced and unbalanced SSG.	✗	LSG	GK + 11 vs 11 + GK	✓	✓	✗	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) Lince software® (Gabi net al., 2012)	Digital video camera for video recording and analysed an ad hoc instrument being used to notate tactical actions (Costa et al. 2011) 15 Hz GPS (SPI-ProX, GPS ports, Canberra, ACT, and Australia)	Dynamic overlap <qd(t)> Trapping strength Boltzmann–Gibbs–Shannon entropy NHST Cohen' d
(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 passing interactions.	✗	SSG		✓	✓	✗	Matlab® routines (Math-Works, Inc., Massachusetts, USA)	5 Hz GPS (SPI-Pro X II, GPS ports, Canberra, ACT, and Australia)	Dynamic overlap <qd(t)>

(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

Abbreviations:<qd(t)> – 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
3 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.