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Origin and modifications of the geometrical centre to assess team behaviour in team sports: a systematic review

Origen y modificaciones del punto geométrico para evaluar el comportamiento táctico colectivo en deportes de equipo: una revisión sistemática

Markel Rico-González[1], José Pino-Ortega[2], Fabio Yuzo Nakamura[3], Felipe Arruda-Moura[4] & Asier Los Arcos[5]

1. Department of Physical Education and Sport, University of the Basque Country, UPV/EHU. Spain
2. Faculty of Sports Sciences. University of Murcia. Spain
3. Associate Graduate Programme in Physical Education UPE/UFPB, João Pessoa, Paraíba, Brazil
4. Laboratory of Applied Biomechanics, Sports Sciences Department, State University of Londrina, Brazil
5. Society, Sports and Physical Exercise Research Group (GIKAFIT). Department of Physical Education and Sport. Faculty of Education and Sport. University of the Basque Country (UPV/EHU), Vitoria-Gasteiz, Spain.

Abstract

The aim of the present study was to systematically review the origin and modifications of the geometrical centre (GC) in the assessment of team behaviour in team sports. Studies were identified following the PRISMA guidelines and PICO design for systematics reviews in four electronic databases (PubMed, SPORTDiscus, ProQuest Central, and Web of Sciences). A total of 3,973 documents were initially retrieved, of which 1,779 were duplicates. After checking 2,178, another 36 were added from the references of the studies. 72 articles met de inclusion criteria and 7 were included for the systematic review. Habitually, the GC is computed as the mean [X,Y] of several or all players in the sports team. Despite the relevance of the location of the players with respect to the goal, habitually, the goalkeeper/target has not been considered in the measurement of the GC. Two techniques (i.e. Hilbert transformation and cluster analyses) have been applied to analyse the synchronisation (i.e. relative phase) and the average mutual information (AMI) to assess the complexity and regularity or predictability of the GC in team sports. Since the GC does not consider the goalkeepers and team dispersion, this measure should be interpreted with caution, but together with other tactical variables can provide interesting information for team sports technical staff.

Key words: collective tactical behaviour; spatial centre; centroid; positioning.

Resumen

El objetivo de este estudio fue revisar sistemáticamente el origen y las modificaciones del centro geométrico (GC) en la evaluación del comportamiento táctico colectivo en los deportes de equipo. La identificación de los estudios se llevó a cabo en cuatro bases de datos (PubMed, SPORTDiscus, ProQuest Central, and Web of Sciences) siguiendo la guía PRISMA y el diseño PICO para revisiones sistemáticas. Un total de 3,973 documentos fueron inicialmente recuperados, de los cuales 1,779 eran duplicados. Después de analizar 2,178 artículos, otros 36 fueron añadidos tras ser rescatados de las referencias bibliográficas. 72 artículos cumplieron los criterios de inclusión, de los cuales 7 sugirieron variables tácticas originales relacionadas con el posicionamiento del GC. Dos cálculos diferentes han sido propuestos para medir el GC en los deportes de equipo, siendo la media [X, Y] de varios o todos los jugadores del equipo el más utilizado. El primer cálculo del GC fue propuesto en fútbol y consideró al portero, pero este jugador especial no suele ser incluido en la medición. La ubicación de los jugadores con respecto a la diana no ha sido considerada para valorar el GC en deportes de equipo como el fútbol. Por lo tanto, las variables tácticas complementarias, como por ejemplo la distancia entre el portero o la portería y el GC podrían asociarse con el GC para evaluar la posición relativa de varios jugadores en el espacio de juego. Dos técnicas distintas (i.e. la transformación de Hilbert y el cluster analyses) han sido aplicadas para analizar la sincronización (i.e. la fase relativa) y el average mutual information (AMI) para evaluar la complejidad y regularidad o previsibilidad del GC en los deportes de equipo.

Palabras clave: comportamiento táctico colectivo; centro geométrico; centroide; posicionamiento.

Correspondence/correspondencia: Asier Los Arcos
Society, Sports and Physical Exercise Research Group (GIKAFIT). Department of Physical Education and Sport. Faculty of Education and Sport. University of the Basque Country (UPV/EHU), Vitoria-Gasteiz, Spain
Email: asier.losarcos@ehu.eus

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Introduction

Although all team sports are different, they share two fundamental structural traits: the presence of teammates and opponents. Thus, team sports are social systems (i.e., collective duels) (Araújo & Davids, 2016; Parlebas, 2002) in which teammates collaborate (i.e., positive interaction) to overcome the opposing team (i.e., negative interaction). This means that team sports players are required to respond constantly to an uncertain environment (i.e., lack of information) due to the interaction with their teammates and opponents. This interaction is determined by the internal logic (i.e., structural traits) (Parlebas, 2002) of each team sport: the possibilities of interacting with other players (e.g., number of players, playing roles), the relation with space (e.g., playing space or m^2 per player, type of goals), the relation with time (duration), and the relation with the mobile (e.g., type of use of the ball). The individual and differential action of each team sport emerges from the response of the players in these specific situations. The result of their decision-making during play can be observed directly using electronic performance and tracking system technologies (Rico-González et al., 2020a, 2020b).

Since Schöllhorn (2003) suggested, among other measures, the geometrical centre (GC) to analyse team sports matches, this approach has been one of the most commonly used to assess the behaviour of the whole team. The GC represents, in a single point computed considering x and y coordinates of the players, the relative positioning of each team in forward-backward and side-to-side movements (Araújo & Davids, 2016). Different terms (centroid (Frencken et al., 2011), centre of gravity (Lames, Ertmer, & Walter, 2010), spatial centre (Bourbousson et al., 2010b), centre of the team (Frencken & Lemmink, 2009)) have been used to refer to the 'same' concept in team behaviour assessment studies. However, to our knowledge, no study has analysed whether these terms are computed in the same way and are conceptually equal. Thus, it is relevant to analyse the origin, modifications, and computation of the GC over the last few decades since its interpretation and the assessment of derivative team behaviour variables (e.g. GC-GC distance, relative phase and entropy) (Bourbousson et al., 2010b; Duarte et al., 2013; Silva, Duarte, et al., 2014; Travassos et al., 2012) could differ considerably.

The application of several data processing techniques (i.e., relative phase and entropy) has been suggested to improve team behaviour analysis. The relative phase was suggested as a collective variable to capture the modes of movement that two oscillators demonstrate during games, showing two patterns of relative motion: in-phase (i.e., the oscillators move in the same direction) and anti-phase (the oscillators move in opposite directions) (Palut & Zanone, 2005). The same concept has been widely used to assess the synchronisation between several types of oscillators such as the GC and players (teammates and opponents) in team sports (Rico-González et al., 2020). On the other hand, entropy (Pincus, 1991) was translated to team sports due to its appropriateness for analysing the results of nonlinear dynamical systems such as sports teams (Passos et al., 2009). This data processing technique has been used to assess the complexity and regularity or predictability of the time series of a system (Silva, Duarte, et al., 2016). It is necessary to review the origin, application (Memmert et al., 2017), and different mathematical concepts and computations applied (Duarte et al., 2013; Passos et al., 2009) to optimise the use of the data processing techniques in the GC.

The aim of the present study was to systematically review the origin and the modifications of the GC in the assessment of team behaviour in team sports.

Methods

Search Strategy

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines (Moher et al., 2010). The protocol was not registered prior to initiation of the project and did not require Institutional Review Board approval. A systematic search of four databases was performed by the authors (MR, ALA, JPO) to identify articles published before 13 November of 2018. The authors were not blinded to journal names or manuscript authors. Moher et al., 2010 design was used to provide an explicit statement of question. The search was carried out using two filters where the database allowed this: journal article; and title (TI)/abstract, except in WoS, which was searched throughout the text. In addition, in the last-mentioned database the sports sciences branch was selected. The search was made using combinations of the following terms linked with the Boolean operators “AND” (inter-group Boolean operator) and “OR” (intra-group Boolean operator). Three main groups were created: 1) “Soccer”, “football”, "team sport*", “basketball”, “rugby”, “handball”, “hockey”; 2) “GPS”, "global position system*", “GNSS”, "Global navigation satellite system*", “UWB”, "ultra wide band", "local position", “LPP”, “LPS”, “EPTS”, "electronic performance and tracking systems*", “video”, “video tracking”, "tracking system*", “electronic*”, "satellite system*", “GIS”, "geographical information system*"; and, 3) “formation*”, “tactic*”, “behaviour*”, “performance*”, “position*”, “spatiotemporal”, “spatio-temporal”, “synchronization*”, “coordination*”, “pattern*”, “synerg*”, “Voronoi”, “Delaunay”, “decision-making”, “decision making”.

Screening Strategy and study selection

When the referred authors had completed the search, they compared their results to ensure that the same number of articles had been found. Then, one of the authors (MR) downloaded the main data from the articles (title, authors, date, and database) to an Excel spreadsheet (Microsoft Excel, Microsoft, Redmond, USA) and removed the duplicate records. Subsequently, the same authors screened the remaining records to verify the inclusion-exclusion criteria, using a hierarchical approach (Table 2) in two phases: Phase 1, titles and abstracts were screened and excluded by two authors (MR, ALA), where possible; Phase 2, full texts of the remaining papers were then accessed and screened by the same two authors (MR, ALA).

Table 1. Inclusion/exclusion criteria

Criteria	Inclusion	Exclusion	Primary Screen type
1	Team sports in which the use of the mobile object (e.g., ball, disc) is simultaneous (e.g. soccer, basketball, rugby, hockey).	Team sports in which the use of the mobile object is alternate (e.g. volleyball, squash, tennis, badminton).	Title/Abstract/Full text
2	The main objective of the study is to assess tactical performance or dimension in team players.	Studies that do not assess the tactical performance or dimension in team sports (e.g., studies that only quantify external training load). Studies that consider referees.	Abstract / Full text
3	Studies that include a tactical variant regarding the position of the players	Studies that do not assess tactical performance or dimension using EPTS.	Abstract / Full text
4	Studies that aim to measure a tactical variable	Studies that aim to assess the validity and reliability of a device comparing it with another in a training task	Abstract / Full text
5	Studies that aim to analyse the position of more than one player, whether they are rivals or not	Studies that analyse the position of the players individually.	Abstract / Full text
6	Studies that measured the GC or modified this variable, and provided their computation criteria.	Studies that measured other tactical variables or did not provide any modification of the GC or computation criteria.	Full text

GC: Geometrical Centre

Any disagreements on the final inclusion-exclusion status were resolved through discussion in both the screening and excluding phases. Moreover, relevant articles not previously identified were also screened in an identical manner and the studies that complied with the inclusion-exclusion criteria were included and labelled as ‘not identified from search strategy’.

Data analysis

The articles that reported an original computation of GC are detailed in Table 2 including their contextual characteristics: term, sport, level of players, task, technology used, and computational characteristics. In addition, the relative phase between two GCs and the predictability of a GC or Average Mutual Information (AMI) were considered (Table 3).

Assessment of methodological Quality

The quality of included studies was individually assessed using a modified assessment scale of Downs and Black by Sarmento et al. (2018). As in other systematic reviews (Low et al., 2020), the quality scores were classified as follows: (1) low methodological quality for scores ≤ 50%; (2) good methodological quality for scores between 51% and 75%; and (3) excellent methodological quality for scores > 75%. Two reviewers (MRG and ALA) applied the quality index to each included study independently and any scoring discrepancies were resolved by consensus of the two researchers. An independent inter-rater reliability analysis was carried out using Cohen´s Kappa value (Cohen, 1960).

Results

A total of 3,973 documents were initially retrieved from the above-mentioned databases, of which 1,779 were duplicates. A further 14 records were removed as they were not articles and another 2 were not found. Thus, a total of 2,178 articles were downloaded. Next, the titles and abstracts were verified against criteria 1-5 and studies were excluded where possible. The full texts and abstracts of the remaining articles were reviewed, and the inclusion/exclusion criteria were applied, leading to the exclusion of 2,142 articles. Therefore, 36 articles were initially included in this review. In addition, reviewing the references of the included articles, the authors found and added 36 articles that met inclusion criteria 1-5. In most of these studies the search tool (group 2) was not detailed in the title or the abstract. Finally, 72 articles were analysed and 65 of them did not fulfil inclusion criteria 6. So finally, 7 articles were included in this systematic review (Figure 1).

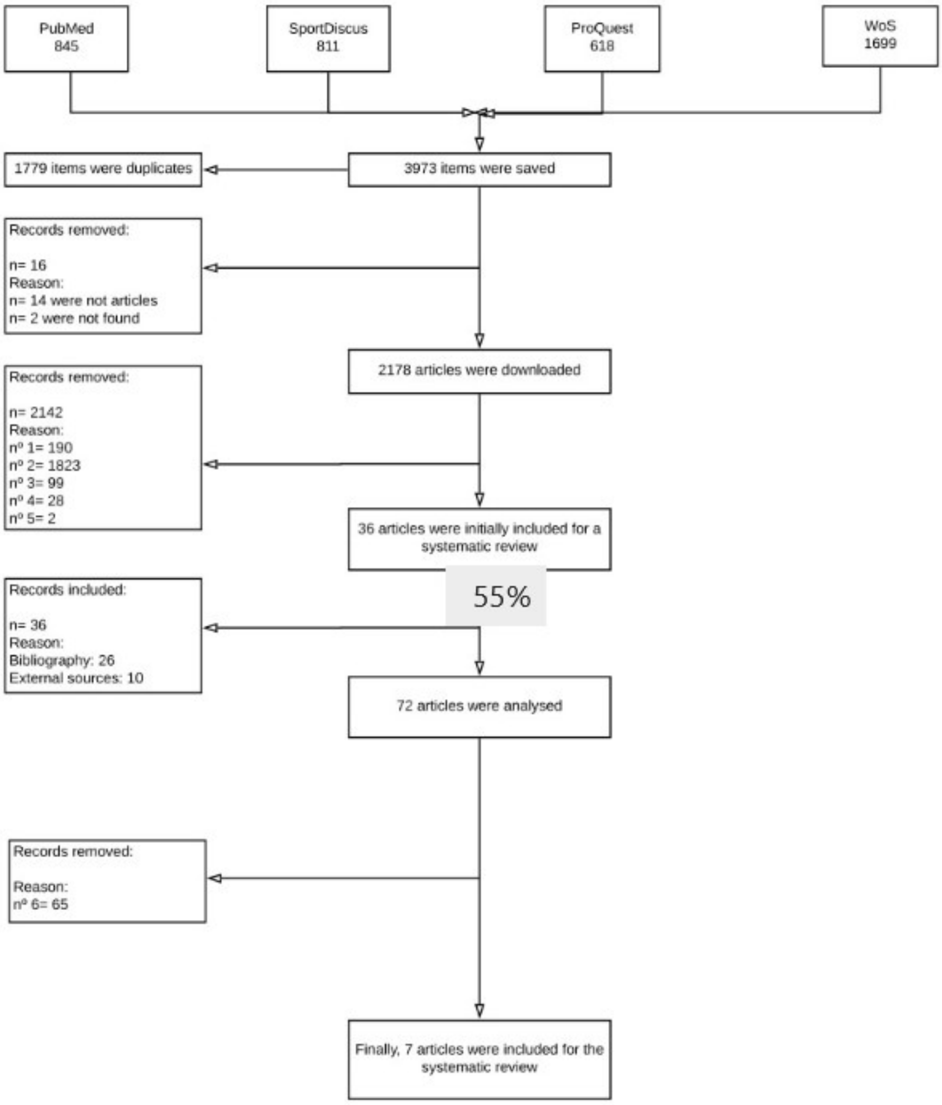

Figure 1. Flow diagram of the study

Assessment of methodological Quality

The inter-rater reliability analysis achieved a Kappa value of 0.93, indicating very good agreement between observers. In the evaluation of methodological quality, the mean score for the Downs and Black modified scale was 82%. All studies had excellent methodological quality (quality score > 75%) (Tables 2 and 3).

Table 2. Origin and modifications of the geometrical centre (GC)

Author	Used Term	Sport	Competition Level	Task	EPTS	Computation	Q
Yue et al. (2008)	Geometrical centre	Soccer	Professional	Soccer match	OPT	Yes	75
Frencken & Lemmink (2009)	Centre of team	Soccer	Youth elite	Small-sided games (9 attacks)	LPM	The mean (x, y) of all players of one team (goalkeepers excluded).	-
Moura et al. (2011)	Centroid	Futsal	Professional	Futsal Challenge match (58 specific situations of shots to goal and 120 tackles)	OPT	The centroid of the geometric form of the team convex hull	81

LPM: local position measurement system; OPT: optic-based systems; Q: Quality score (%)

Table 3. Origin and modifications of the application of the data processing techniques in the Geometrical Centre (GC)

Data processing technique	Author	Variable	Sport	Competition Level	Task	EPT S	Computation	Q
Relative phase	Bourbousson et al. (2010)	Spatial centres of the two teams	Basketball	Professional	Match	OPT	Hilbert transform	81
	Travassos et al. (2012)	Defending team-attacking team	Futsal	National Futsal University	5 vs.(4+GK)	OPT	Hilbert transform	88
	Duarte et al. (2013)	Team-team-player	Football	Professional	Match	OPT	Cluster phase analysis	81
AMI	Silva, Duarte, et al.,(2014)	GC-GC	Soccer	Young (regional and national level)	(4 + GK) vs. (4 + GK)	GPS	Yes (Silva, et al., 2014)	88

AMI: Average mutual information**;** GPS: Global Positioning System; OPT: optic-based systems; Q: Quality score (%)

Discussion

The aim of the study was to systematically review the origin and the modifications of the GC in the assessment of team behaviour in team sports. Habitually, the GC is computed as the mean [X,Y] of several or all players of the sports team. Despite the relevance of the location of the players respect to goal, habitually, the goalkeeper/target has not been considered in the measurement of the GC. Two techniques (i.e. Hilbert transformation and cluster analyses) have been applied to analyse the synchronisation (i.e. relative phase) and the AMI to assess the complexity and regularity or predictability of the GC in team sports.

Linear analysis

<u>*Origin and modifications*</u>

More than 20 years ago, Schöllhorn (2003) proposed, among other measures, the geometrical centre (GC) (i.e., the common centre of gravity of several or all team members) in order to quantify tactical behaviour in team sports. However, this tactical variable was not measured in team sports until 2008. Yue et at. (2008) calculated the GC (they also used this term) of two teams as functions of time to assess its amplitude in longitudinal and lateral directions and its movements regarding the ball during a professional soccer match (Yue et al., 2008). The authors defined the GC of each team, including goalkeepers, in both directions distinctly (i.e., x and y) (Yue et al., 2008). In this regard, Silva, Chung, et al. (2016) suggested that the differentiation of the movement analysis into separate directions may not be necessary due to fact that the typical attacking-defending nature of a match predominantly occurs in the goal to goal direction, and different players may perform coordinated movements both laterally and longitudinally, such as a fullback moving laterally to create greater space, while a winger moves forward to an advanced position (Low et al., 2020). Thus, all or some (i.e., subgroups (Duarte et al., 2012; Gonçalves et al., 2014; Silva, Travassos, et al., 2014)) outfield players, according to the team sport, are often considered to represent, in a single variable, the relative positioning of each team in both forward-backward and side-to-side movements together (Araújo & Davids, 2016).

The first modification of the computation, made by Frencken & Lemmink (2009), who used the term centre of team, did not consider the goalkeeper and did not separate the computation in x and y coordinates to measure GC. They defined the centre of team as the mean [X,Y] of all players of the team (Frencken & Lemmink, 2009). In several sports, the constant interaction between the goalkeeper and the rest of the players, that is, the influence of one of the most relevant structural traits of some sports (i.e., the orientation in the space) on the players´ decision-making was not considered to measure the GC. So, since the goalkeeper determines the collective tactical behaviour of the team (Sarmento, Anguera, Pereira, & Araújo, 2018), it is suggested to include this special player in the assessment of the GC. Further studies should assess how the goalkeeper's position affects the GC in different types of team sports tasks and according to the location of the ball on the field during the matches because several tactical variables are measured based on the GC; for example, several distance variables such as GC-GC, GC-player, GC-space, GC-ball and GC-goal (Rico-González et al., 2020b)

The second modification was suggested by Moura et al. (2011), based on the work of Graham (1972), the authors proposed a different mathematical computation, the centroid of the geometric form of the team's convex hull, to measure the GC during a futsal match (Moura et al., 2011). As the calculation by Moura et al. (2011) may ignore the positioning of some players and therefore, not provide any information to the coach, the majority of studies apply the mathematical concept suggested by Yue et al. (2008) and Frencken and Lemmink (2009) (i.e. *the mean [X,Y] of all players of the team*) (Low, et al., 2020; Rein & Memmert, 2016; Rico-

González et al., 2020b), but, if applicable, exclude the goalkeeper to measure the GC (also named centre of gravity (Lames, Ertmer, & Walter, 2010) and spatial centre (Bourbousson et al., 2010b).

The use of the GC in team sports

The GC is a general value (i.e. macro-structure) that represents, in a single point computed considering the x and y coordinates of the players, the relative positioning of each team in forward-backward and side-to-side movements (Araújo & Davids, 2016). Thus, the GC assumes a lack of information as different team formations could be represented by the same GC value. In addition to not considering team dispersion, the computation of the GC habitually does not consider the goalkeeper. For these reasons, this measure should be interpreted with caution.

Despite its limitations, the GC can be an interesting tactical variable for team sports technical staffs. On the one hand, the GC can be used to assess collective tactical behaviour at sub-group level (Travassos et al., 2013). This makes possible the analysis of the interactions within special sub-systems of the team during play (Grehaigne et al., 1997). One example of this is the mean position of the team formation´s line (i.e. backs, midfielders or forwards) (Gonçalves et al., 2014). On the other hand, the GC can be used to assess the relation (i.e. distance) from GC to a specific player, special space location or the ball, the inter-team coordination (i.e., coupling stretch and relative phase), and the "pressure" index between teams (Rico-González et al., 2020b).

Non-Linear analysis

Synchronization

The assessment of the synchronisation was proposed by Schmidth, O´ Brien & Sysko (1999), who explained that two oscillators of the opposite teams are in-phase until the attacking oscillator achieves an imbalance on the opposite oscillator´s movements, which allows a scoring opportunity. Although the first studies on the assessment of team behaviour represented and compared the movements of the GCs (Frencken & Lemmink, 2009; Yue et al., 2008) and the values of the surface areas (Frencken & Lemmink, 2009) and radius (Yue et al., 2008) of the two teams during soccer SSGs and matches, the relative phase was not computed. This technique was applied for the first time in team sports by Bourbousson et al. (2010b, 2010a) and Lames, Ertmer and Walter (2010) in basketball and soccer, respectively. Bourbousson et al. (2010b, 2010a) computed the relative phase for the spatial centres and stretch indexes of both teams and for intra- and inter-team dyads and Lames, Ertmer and Walter (2010) measured the relative phase of the GCs and ranges of both teams. In addition, Travassos et al. (2012) measured the relative phase of the GCs by the Hilbert transform when the goalkeeper of the attacking team was substituted for an extra outfield player in futsal.

The assessment of the relative phase allows capturing the modes of movement that two oscillators demonstrate during games (i.e., in-phase and anti-phase) (Palut & Zanone, 2005) and has been widely used to assess the synchronisation between several types of oscillators in team sports (Rico-González et al., 2020b). It could be interesting to measure the ssynchronisation between both team´s GC to assess how in anti-phases it is related with goal scoring opportunities (Lames, Ertmer, & Walter, 2010; Schmidt, O´ Brien, & Sysko, 1999), and between GC-team player to assess how the players adapt according to the team´s relative positioning (Sampaio & Maçãs, 2012). However, in order to link these viewpoints and evaluate the synchronisation between more than 2 oscillators, based on the proposal of Kuramoto (1984) and the adaptation of Frank and Richardson (2010), Duarte et al. (2013) applied the cluster method in team behaviour analysis. Specifically, Duarte et al. (2013) used the cluster method to measure whole team and player–team (i.e. GC-GC-player) synchrony.

Predictability

Since Pincus (1991) emphasised the application of the entropy in a variety of contexts, this technique has been widely applied to assess the predictability of the GC and other oscillators (Silva, Duarte, et al., 2016) considered a dyad (Rico-González et al., 2020b). Silva et al. (2014), introduced the average mutual information (AMI) as a measure of information that one random variable (e.g. team´s GC) contains about another random variable (e.g. opposing team´s GC) in both longitudinal and lateral directions. This method allows quantification of the information on one variable, through checking the other variable. So, it is the reduction in the uncertainty of one random variable due to the knowledge of the other (Cover & Thomas, 2005).

Conclusion

Two different computations have been suggested to measure the GC in team sports, with the mean [X,Y] of several or all the players of the team being the most used. Although the original GC considered the goalkeeper to compute this tactical variable in soccer, this special player is not usually included in the measurement. The location of the players with respect to the goal is not considered to assess the GC in team sports such as soccer. Thus, complementary tactical variables, like for example the distance between the goalkeeper or the target and the GC could be associated with the GC in order to assess the relative positioning of several players in the playing space. Two techniques (i.e. Hilbert transformation and cluster analyses) have been applied to analyse the synchronisation (i.e. relative phase) and the AMI to assess the complexity and regularity or predictability of the GC in team sports.

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