Systemic Mapping of High-Level Women's Volleyball using Social Network Analysis: The Case of Attack Coverage, Freeball, and Downball

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ABSTRACT This work analysed team sports as complex systems in which behavioural variables need to be taken into consideration when studying performance. Within this understanding, the use of Social Network Analysis constitutes a useful research path. As such, this research analysed two of the least studied game complexes: attack coverage and freeball and downball, in eight matches from the first Group Stage of the Women's World Grand Prix 2015, comprising a total of 1,264 rallies. Eigenvector centrality values were calculated, with each behavioural variable counted as a node and their connections as edges. The results showed that playing in off-system is central in both complexes, although more so in attack coverage than in freeball and downball situations. Results also showed that although freeing a higher number of players for attack action is potentially advantageous, such action would become a disadvantage when faced with an effective blocking action and the sudden need for effective attack coverage. Overall, this study showed that volleyball coaches should take off-system game moments into stronger consideration and devise a strategy of play that will turn off-system play into an advantage.

KEY WORDS Off-system Gameplay, Performance Analysis, Social Network Analysis, Volleyball.

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Introduction

The study of networks pervades all of science, from neurobiology to statistical physics (Strogatz, 2001). In fact, although systemic analysis has existed for several decades (see the General Systems Theory developed in the first half of the 20th century by Bertalanffy (1950) and Boulding (1956), among others), in the last two decades a wider range of scientific fields have been displaying a broader interest in research into complex systems (Strogatz, 2001). Furthermore, recent trends in the psychology of learning, namely in embodied cognition, stress the learner-environment relationship, stating that learning takes place in dynamic contexts with the acquisition of knowledge occurring as a consequence of indeterminate interactions between learners and the environment (Barab & Kirshner, 2001). As such, performance and learning should be viewed as "constrained by key features of the organism-environment system including the structure and physics of the environment, the biomechanics and morphology of individual and specific task constraints" (Chow, Davids, Hristovski, Araújo, & Passos, 2011, p.190).

Learning and performance are two tenets of any sports activity and, as such, any study of sports performance would benefit from an approach that considers the systemic relation between the desired action outcome and its constraints. Traditionally an analytical approach in science breaks down a system into its simplest components while considering that the introduction of a change in a variable would allow the deducing

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of general laws, which would, in turn, allow predicting properties of the system under different conditions (Gréhaigne, Bouthier & David, 1997). However, the additive laws at play in the aforementioned deduction process do not function in complex systems making necessary the use of a systemic approach (Gréhaigne et al., 1997). Before the emergence of systemic analysis, the formal approaches used for explaining phenomena had been linear, stepwise, and sequential in nature, but formal methods relying on rational sequential logic are of limited utility for problems emerging from complex systems (Keating, Kauffman & Dryer 2001).

Sports, particularly team sports, can, therefore, be approached in a productive manner using the framework of non-linear, complex systems. Regarding such an approach to sports activity, the works of McGarry (with Anderson, Wallace, Hughes & Franks in 2002, and with Franks in 2006) and Lebed (2006 & 2007) demonstrate two different approaches. The first states that a sports contest can be considered as a non-linear and self-organizing system, based on dynamic principles. The same author also states "a dynamical system is a type of complex system, one which regularity self-organizes from within as a result of information exchanges that occur both inside and outside the system" (2006, p.48).

In contrast, Lebed (2006), in response to McGarry (2002), stated that although opponents competing could be interpreted as a symbiotic relation, and therefore as a system, such a concept "is nothing but an appearance of systematic wholeness" (2006, p.36). This impossibility of wholeness occurs, according to Lebed (2006), because of the antagonistic feature of the match itself, where each team's aim is directly opposed to the other's. As such, according to Lebed "the one case in which the game process becomes a system is a cooperative game" (2006, p.36). Independently of particular takes such as the two exemplified by the quotes above, the usefulness of a systemic approach is prevalent in team sports (McGarry 2002; Lebed 2006), in as much as there are several interactions between elements on both teams.

While taking sports as a complex system, McGarry (2009) underlines six issues that can affect performance analysis of which two are of particular relevance to this study: a) the interactions between opposing players and/or teams as being key for interpreting game behaviour, and b) the context in which sports behaviours are produced as offering valuable information for game analysis. Both points underline the importance of a systemic analysis in sports performance, and the need for researchers to focus on the effects emerging from the interactions between variables and sets of variables. In fact, according to Gréhaigne, Godbout, and Bouthier "in any team sport, players are faced with four interrelated tasks: an attack on the adverse camp, defence of their own camp, opposition to opponents, and cooperation with partners" (2001, p. 60). The opposing team can thus be conceptualized as "problem" in as much as it stands in the way of the other team's victory. Effective problem solving for complex issues will do better with an approach capable of addressing the uncertain dynamic behaviour that is characteristic of complex systems. Thus, the option for a systems approach analysis in problem solving will provide an overall consideration of the 'problem system' in which there are two critical points: (1) problems cannot be isolated from the system that is producing the problematic behaviour; and (2) the problem system cannot be understood independently of the context within which it is embedded (Keating, 2001). Taking team sports as open/complex systems and considering ineffective play action as the problem, we can see how contextual and behavioural variables need to be taken into consideration when studying ways to improve team performance.

In volleyball, different types of variables have been studied and analysed. However, few studies have focused on systemic mapping of the relationships between sets of variables (see Costa Afonso, Barbosa, Coutinho, and Mesquita. (2014) and Marcelino, Afonso, Moraes, and Mesquita. (2014) for exceptions). As Reed and Hughes (2006) stated in relation to patterns formed in open (complex) systems, "small changes to the system prompt large (nonlinear) changes in the system" (p.114). Due to this complexity, Sports Sciences have been investing in methods to enhance the training processes; one such promising method is Social Network Analysis (SNA). This latter method, with its foundation in the mathematical field of Topology, is useful in addressing the issue of interdependencies in the data inherent in team structures (Lusher & Robins 2010), both in quantitative (e.g. number of connections) and qualitative terms (e.g. degree and quality of connectedness). As such, SNA proves to be useful in identifying and measuring the centrality of game variables, which will deliver useful information for planning and developing team tactics and their intrinsic dynamics.

This research uses SNA to scrutinize how two often-neglected game complexes operate in high-level women's volleyball: attack coverage (KIV), and – freeball and downball (KV; two of the less studied complexes in volleyball, probably because they occur in a minor percentage of the game in comparison to the other complexes). Competition in high-level volleyball has evolved to such a demanding level of performance, that every opportunity to score a point should be valued (Laporta, Nikolaidis, Thomas & Afonso, 2015). As such, freeball and downball situations, although occurring in a smaller percentage in relation to the other game complexes, are important and should be studied so that a team can ensure scoring in a favourable situation. In women's volleyball, it is common to have longer rally points than in men's volleyball (Esper, 2003). The former occurs because there are several situations of KIII and KIV, where in the latter, a team can recover the ball possession after the opponents' block. As such, it is important to study KIV, especially in women's volleyball, because it will allow a team to regain an opportunity to score and thus produce a more efficient sports performance.

Methods

Sample

The analysed World Grand Prix games were part of two groups: Group A – Brazil (3rd place in the competition and 3rd place in the rankings of the Fédération Internationale de Volleyball - FIVB); Japan (6th place in the competition and 5th in the FIVB ranking); Serbia (8th place in the competition and 6th place in the FIVB ranking) and Thailand (9th place in the competition and 13th in the FIVB ranking). Group B – Russia (2nd place in the competition and 4th in the FIVB ranking); China (4th place in the competition and 2nd in the FIVB ranking); Germany (7th place in the competition and 11th in the FIVB ranking) and the Dominican Republic (12th place in the competition and 7th in the FIVB ranking). In the process, a total of eight matches (29 sets; 1,264 rallies) were analysed.

Instruments

The video recordings of the matches offered both a lateralized view (aligned with the net) and an overview of the court. The recordings of the eight matches were freely available on the site youtube.com. In terms of observers involved in the study, the former were previously trained so as to guarantee consistency in the coding data criteria register, both for intra- and inter-observer reliability calculations. This previous training consisted of viewing and registering eight games from different high-level competitions (men and women). A minimum level of 0.75 for Cohen's Kappa calculation of reliability was established. All registered variables resulted in Kappa values above 0.81.

Variables

In this research six-game complexes were considered (Muñoz, 2007): serve (K0), side-out (KI), side-out transition (KII), transition (KIII), attack coverage (KIV) and freeball and downball (KV); the latter two were analysed. Court zones were defined according to the FIVB game rules. Some variables occur in both complexes, while others are unique to each complex. As such, the common variables to both KIV and KV are the setting zone, attack zone, and attack tempo. The variables that differentiate the two complexes are the number of attackers' available pre-KIV and the number of coverage lines (within KIV), and freeball or downball distinction, and ball within front row or back row of the court (within KV).

KIV is the only complex that can follow all other complexes (except for K0), as it is defined as the act of regaining ball possession immediately after the ball having been deflected by the opposing team's block and returned to the attacker's court (Laporta et al. 2015). As such, according to the latter authors and to Selinger and Ackermann-Blount (1986), the variables in KIV are: number of attackers available pre-KIV, which refers to the number of players available before the setting to attack the opposing team (register of observed data done from 1 player available up to a maximum of 4 players); number of coverage lines - this refers to the number of lines that constitute the attack coverage system (register of the observed data done from a minimum of 1 line up to a maximum of 3 lines); setting zone (register made following Laporta et al. (2015) and adapted from Esteves and Mesquita (2007): A- the setter can play with all of his attackers; B- the setter has space-time difficulties to set to the middle blocker, although he can still set quick plays to the outer players; C- the setter has only the options to set to the outer hitters); attack zone (Zones 1 to 6); attack tempo (register made following Afonso and Mesquita (2007) and Costa, Afonso, Brant, and Mesquita (2012): 1- the attacker is in the air, or will be jumping during or rapidly after the setting; 2- after the setting the attacker takes two steps; 3- the attacker takes three or more steps after the setting).

The KV complex encompasses freeball situations or downball situations (Hileno & Buscà, 2012). As such, the variables of this complex are: distinction between freeball - the opponent delivers a ball with no aggressive/powerful intention, and downball - the ball has a more downwards trajectory than the freeball and can be more unpredictable; target zone of KV (attack zone - Zones 2, 3 and 4; or defence zone - Zones 1 to 6); setting zone, attack zone and attack tempo also are a part of KV, and have the same definition as presented above for KIV.

Statistical analysis

Social Network Analysis was performed using the measurement of eigenvector centrality. The data collected was initially registered on an Excel® worksheet and then subjected to statistical analysis using IBM® SPSS® Statistics (Version 21, U.S.A.) to perform quality control and exploratory cross table statistics of the data. The eigenvector centrality measure was obtained by using the software Gephi© 0.8.2-beta (Version 10.10.3, France). The insertion of the collected data in this software produced a total of 43 nodes and 356 bridges. Eigenvector centrality (Bonacich, 1972) is a concept based on the idea that a node is more central if it is related with nodes that are themselves also central. As such, the centrality of a node does not depend solely on the number of its adjacent nodes but also on their characteristics.

Concerning the reliability of the statistical procedures undertaken, and the previous testing of the instrument notwithstanding, specific testing was performed. For the purposes of the inter-observer reliability of the analysis of the current sample, 50.9% (n = 216) of the rallies were reanalysed (above the 10% suggested by Tabachnick & Fidell, 2000). Cohen's Kappa values respected the minimum value of 0.75 suggested in specialized literature (Fleiss, 2003), having ranged from 0.81 to 1.

Results

The overall Social Network Analysis mapping is presented below.

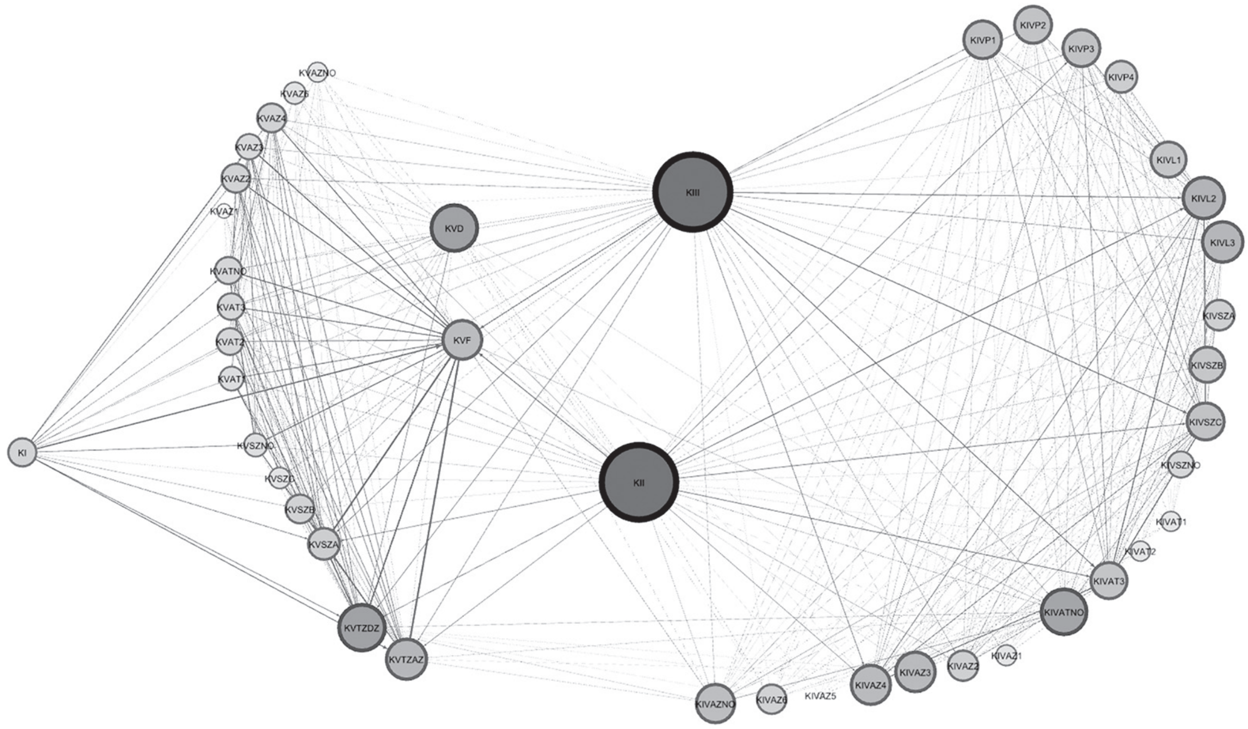

FIGURE 1. Overall mapping of the Social Network Analysis (Gephi Software)

Concerning KIV (see Table 1), the eigenvector values obtained for the number of attackers available pre-KIV were very similar (KIVP1 with a value of 0.55, and KIVP2 and KIVP3 with a value of 0.54). Regarding the category number of coverage lines, two values stood out: coverage lines with two and three lines (KIVL2=0.59 and KIVL3=0.62, respectively). Concerning the setting zone, zones associated with off-system playing (i.e. under non-ideal conditions: KIVSZC=0.54 and KIVSZB=0.52) presented the highest eigenvector values. The two highest values found within the attack zone belonged to KIVAZ3 and KIVAZ4 (both with a value of 0.57). Finally, within the attack tempo category, KIVATNO (0.64) has the highest value, very much above that of KIVTA3 (0.53), the second highest register.

TABLE 1 Eigenvector Values for Attack Coverage

Number of attackers available pre-KIV (KIVP)	One attacker (KIVP1)	Two attackers (KIVP2)	Three attackers (KIVP3)	Four attackers (KIVP4)			
	0.55	0.54	0.54	0.48			
Number of coverage lines (KIVL)	One line (KIVL1)	Two lines (KIVL2)	Three lines (KIVL3)				
	0.52	0.59	0.62				
Setting Zone (KIVSZ)	SZ A (KIVSZA)	SZ B (KIVSZB)	SZ C (KIVSZC)	SZ Not Occurring (KIVSZNO)			
	0.46	0.52	0.54	0.41			
Attack Zone (KIVAZ)	AZ 1 (KIVAZ1)	AZ 2 (KIVAZ2)	AZ 3 (KIVAZ3)	AZ 4 (KIVAZ4)	AZ 5 (KIVAZ5)	AZ 6 (KIVAZ6)	AZ Not Occurring (KIVAZNO)
	0.34	0.46	0.57	0.57	0.17	0.45	0.56
Attack Tempo (KIVAT)	AT 1 (KIVAT1)	AT 2 (KIVAT2)	AT 3 (KIVAT3)	AT Not Occurring (KIVATNO)			
	0.33	0.34	0.53	0.64			

Regarding KV (see Table 2), the most common ball type was downball (0.65), as opposed to freeball (0.56), and the target zone that was more commonly solicited was the defensive zone (KVTZDZ=0.65). The highest eigenvector value for setting zone was found within Zone A (0.48), followed by Zone B (0.44). Regarding the variable attack zone, there were two zones with the same high eigenvector value (0.44), Zone 2 and Zone 4, followed closely by Zone 3 (0.40); it is important to underline that there were no attacks performed in Zone 5 and, as such, this category was excluded from the table. Regarding attack tempo all four categories presented relatively close values, with KVTA1 having the only different value from all other categories (0.38 eigenvector value, as opposed to the 0.42 found in all others).

TABLE 2 Eigenvector Values for Freeball and Downball Situations

Freeball or Downball (KVFOD)	Freeball (KVF)	Downball (KVD)				
	0.56	0.65				
Target Zone of KV (KVTZ)	Defense Zone (KVTZDF)	Attack Zone (KVTZAZ)				
	0.65	0.59				
Setting Zone (KVSZ)	SZ A (KVSZA)	SZ B (KVSZB)	SZ C (KVSZC)	SZ Not Occurring (KVSZNO)		
	0.48	0.44	0.35	0.37		
Attack Zone (KIVAZ)	AZ 1 (KVAZ1)	AZ 2 (KVAZ2)	AZ 3 (KVAZ3)	AZ 4 (KVAZ4)	AZ 6 (KVAZ6)	AZ Not Occurring (KVAZNO)
	0.27	0.44	0.40	0.44	0.36	0.33
Attack Tempo (KVAT)	AT 1 (KVAT1)	AT 2 (KVAT2)	AT 3 (KVAT3)	AT Not Occurring (KVATNO)		
	0.38	0.42	0.42	0.42		

To conclude, Table 3 presents the eigenvector values of the three complexes that will not be discussed in this paper. As can be seen in the table below, KIII and KII have much higher eigenvector values than KI.

TABLE 3 Eigenvector Values for Side-out, Side-out Transition, and Transition

Side-out (KI)	***Transition (KII)***	***Side-out Transition (KIII)***
0.43	0.99	1.00

Discussion

Learning and performance are tenets of any sports activity and should be viewed as being constrained by key features of the organism-environment system (Barab & Kirshner, 2001). As such, the study of sports performance would benefit from an approach that considers the systemic relation between the desired action outcome and its constraints. Therefore, while a wide body of research using Match Analysis has focused on the efficacy of actions, here the focus was on the behavioural aspects of performance. This paper analysed two complexes of the volleyball game, namely attack coverage (KIV) and freeball and downball (KV), in women's high-level matches. The analysis was based on SNA, namely measuring the eigenvector values of each complexes' variables.

The data collected for KIV showed that (within the variable number of attackers available pre-KIV) the most common situation was having only one player available for an offensive action before an attack coverage (KIVP1=0.55). If the team that is going to be in KIV only has one player available to attack, it is more likely that the opposing team will have a more cohesive block formation to prevent a successful attack. The availability of only one attacker pre-KIV might promote the possibility of a routinized intention to participate in attack coverage, resulting in attributing a high importance to KIV, notwithstanding its low presence in the game. This latter characteristic should be taken into consideration in team sports coaching, as it shows that a low occurrence in the game may, nevertheless, represent a significant opportunity to gain some advantage. Such a characteristic of team sports dynamics was made apparent by Lorenzo et al. (2010), as they presented situations that were less frequent but nonetheless had a direct relation to winning in U-16 male basketball (see reference to turnover in the close games category). However, the situations with two and three attackers available have registered values very close to the one attacker situation (KIVP2 and KIVP3 both with 0.54 eigenvector). The noticeable difference was when there were four attackers available (KIVP4=0.48). In this situation, the degree of uncertainty faced by the opposing block was higher. As such, the blocking action might be less effective under such constraints. Consequently, the attacking team would benefit from a situation in which there is a smaller need for attack coverage. This would be an advantage, but in the case of an effective block action the attacking team, by having four players in attacking mode, would not have the necessary elements available for attack coverage action.

Recent studies (such as Laporta et al., 2015) carried out on coverage lines showed this game complex is not as structured a system as previously thought. In fact, there was high variability in the disposition of the players within the coverage line(s), as this emerged as a consequence of the momentary constraints of the game, and not a structured, previously developed formation. Coverage lines thus seem to be created out of the players' availability, and this is influenced by several factors of the game both within the attacking team and the opposing team. Regarding the variable number of coverage lines, the highest eigenvector value registered in this study was found within the category two coverage lines (KIVL2=0.59). The category three coverage lines emerged as a close second (0.58), while one-line coverage had the lowest eigenvector value (0.52). This data is in agreement with the results found by Laporta et al. (2015), for which the authors found the same relative frequency of coverage lines: two coverage lines occurred in 60.3% of the KIV situations, followed by three coverage lines (33.6%) and finally only one coverage line (4.7%). However, the data collected in this study showed a smaller difference in frequency of these coverage line scenarios, since all the coverage frequencies observed in this study stood much closer in range.

The results for the variable setting zone showed that in KIV the highest value belonged to Setting Zone C (0.54), followed by Setting Zone B (0.52), showing that in KIV it was more common to construct play in off-system situations. The higher presence of Setting Zones B and C is probably a result of the unpredictable ball deflection from the opposing block. This unpredictability results in the unavoidability of playing off-system. In fact, when following an environmental and systemic approach to team sports analysis off-system situations should be understood to be highly relevant. According to Silva, Garganta, Araújo, Davids, and Aguiar, (2013, p.767) in their study on team coordination, "in most sports, there is no time for team members to plan deliberately during performance, which leads to no other option than ongoing adaptation of behaviours". Thus, teams who can set under less favourable conditions, and also have players (not only the setter) who can perform a second contact with reasonable quality would be in an advantageous position.

Concerning the variable attack zone, two categories stood out: Attack Zone 3 and Attack Zone 4 (both with an eigenvector value of 0.57). However, bordering this value was the value found in the category KIVAZNO (0.58). It was expected that, in an off-system situation, Zone 4 would be a clear option, as it is an outer net zone and therefore easier to set the ball there (Castro and Mesquita, 2008). For the same reason, the high value of Zone 3 comes as a surprise, as it is a central net zone, and therefore it is more difficult to set, especially with the registered higher occurrences of Setting Zones B and C. The fact that KIVAZNO has a high presence in the collected data shows that teams cannot perform a jumping attack very often. This means that when there is coverage, and after a first and second contact, teams would (a) return the ball to the opposing side in a non-aggressive gesture (freeball), (b) return the ball to the opposing side with some aggressive gesture, e.g. a non-jumping attack (downball) or (c) wouldn't be able to return the ball to the opposing side. A wider availability of attack zones could work as a way to increase the opponents' uncertainty and therefore could be a way to enhance the team's success. Therefore, coaches should practice KIV gameplay using different attack zones, either by refining the ability to set to several areas or by having more attacking players available.

Regarding attack tempo in KIV, the eigenvector value with the most influence was found in the category KIVATNO (0.64). This value could have the same threefold explanation as the category KIVAZNO referred to above. The second highest eigenvector value found was 0.53 (KIVAT3), representing the slowest attack tempo. It is expected that with a more off-system type of play slower attack tempos would emerge. Therefore, as a way to improve women's volleyball play in KIV, teams should practice in order to be able to use quicker attack tempos even under non-ideal conditions. These latter tempos would work as a way to unbalance the opposing block formations and consequently improve the chances of winning the point for the attacker (Afonso and Mesquita, 2009).

With respect to KV, data showed that there was a clear distinction between the eigenvector values obtained for freeball (KVF=0.56) and downball (KVD=0.65) situations. This means that when teams are forced to return the ball in less favourable conditions, they play the ball in a way that creates more difficulty for the opposing team (downball). Thus, in future studies, it would be an advantage to keep the distinction between these two types of ball return, as they could produce different results. Possibly, the suggestion to separate them into different game complexes would be reasonable. There is also a clear difference within the category target zone of KV as the defence zone had an eigenvector value of 0.65, compared to the 0.59 value obtained by the attack zone. This difference could be explained by the teams' need to have more time to reorganize their block and defence formations: something made easier by a longer ball trajectory.

The data collected for the category setting zone displayed zone A (0.48) as the most central category. This value could be expected in as much as the ball that is returned in freeball or downball usually has a very low degree of difficulty. Nonetheless, the values of KVSZB (0.44) and KVSZNO (0.37) were relatively close to KVSZA. The KVSZNO value emerged with some influence within KV possibly because it comprises situations in which the ball was returned after a first contact and a net player would be able to attack or block the ball instantly. Although Setting Zone C registered the lowest value (0.35), it showed that even when the returned ball was not challenging there was still off-system playing. In future studies, it might prove useful to separate downball and freeball situations to assess when Setting Zone C occurs.

For attack zones, Zones 2 and 4 exhibited the highest values (both with 0.44), followed closely by Zone 3 (0.40). These values show a predominant and widespread use of the front row within KV, which could be expected in association with the high value of KVSZA. It is important to underscore that there were no registered attacks within Zone 5 in KV, probably a result of the libero's presence. However, exploring a greater diversity of attack zones in KV, namely the use of Zone 5, could become an advantage, as it would create more uncertainty to the opposing teams' block formations. Regarding attack tempo, the highest eigenvector value was 0.42, and it was found in three of the four available categories (KVAT2, KVAT3, and KVATNO). These values show that (a) even when with favorable conditions to build-up play, teams do not use the faster attack tempo available (Attack Tempo 1) and (b) KVATNO is related to situations in which the ball is returned after a first contact (as described above in relation to KVSZNO). The KVAT2, KVTA3 and KVATNO common value could be related to the value of KVSZC. The fact that the value found within attack tempo 3 is relevant in KV, supports the fact that in KV there is also a need to play in off-system conditions, as this is the slowest tempo available, and it is usually associated with Setting Zones B and C. These findings strengthen the argument in favor of teams increasing their use of quicker attack tempos, namely Attack Tempo 1, thus diminishing the opposing teams' block cohesiveness (Afonso and Mesquita, 2009).

Conclusion

This research underscored the usefulness of SNA in high performance sports analysis in as much as it allows for the relational study of a high number of variables present in a match situation. Of particular importance, eigenvector centrality emerged as a useful metric, as it represents more than the simple number of connections each node establishes, instead of weighing those connections with the number of secondary and higher-order connections. It was further demonstrated that by separating the game into different complexes, distinct patterns become apparent: a fact that is relevant in helping to provide guidelines for volleyball coaching. The paper focused on two of the less studied complexes in the game (KIV and KV) and, as such, the data collected will be of use for those interested in a deeper analysis of game strategies. This investigation further showed that playing in off-system conditions was frequent in both complexes, although more so in KIV than in KV; volleyball coaches should, therefore, take into stronger consideration the off-system game moments and devise a strategy of play that could turn off-system play into an advantage and not a difficulty.

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