# A Comprehensive Mapping of High-Level Men's Volleyball Gameplay through Social Network Analysis: Analysing Serve, Side-Out, Side-Out Transition and Transition

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ABSTRACT A deeper understanding of the factors behind performance and their interactions is essential to promote better training practices. Notwithstanding, the focus often relies on the outcomes of players' actions (e.g., efficacy rates), whereas the nature and variations of particular classes of actions remain largely unexplored. Our purpose was to conduct a systemic analysis of categorical game variables and their interactions using Social Network Analysis. Game actions were counted as nodes and their interactions as edges. Eigenvector centrality values were calculated for each node. Eight matches of the Men's World Cup 2015 were analysed, composing a total of 27 sets (1,209 rallies). Four game complexes were considered: Complex 0 (Serve), Complex I (Side-out), Complex II (Side-out transition) and Complex III (Transition). Results showed that teams frequently play in-system when in Complex I (i.e. under ideal conditions), but present reduced variation with regard to attack zones and tempos, whereas in Complex II teams most often play out-of-system. Based on these findings, it was concluded that practicing with non-ideal conditions is paramount for good performance in Complex II. Furthermore, most literature combines Complex II and Complex III as a single unit (counter-attack); however, our results reinforce the notion that these two game complexes differ and should be analysed separately.

KEY WORDS Performance Analysis, Systemic Analysis, Social Networks, Game Logic.



## Introduction

The study of dynamic systems has revealed the existence of common logical principles between social and biological behaviours (Mendes, 2010). Indeed, it is widely recognized that the collective performance of a sport team is more (or less) than the sum of each players' performance (McGarry, 2009). In team sports, different players cooperate to achieve success, such as scoring a goal or blocking the ball, for example (Clemente & Mendes, 2015). Thus, the team acts like a dynamic system, in which different components/parts work together and often produce novel, emergent behaviour, while the overall systemic behaviour retroacts upon the parts (Palomares, 2008). Dynamic systems usually present subsystems that are highly complex and can exhibit partial independence (for example, cell organelles function partially independently, albeit concurring to the overall, systemic pattern of the human body) (Lebed, 2007). The coordinated activity of those subsystems and their interaction support their behaviour and their function (Walter, Lames, & McGarry, 2007). The partial independence of the subsystems contributes to create some instability in the system, leading to the emergence of new patterns or, alternatively, a return to previous patterns (McGarry, Anderson, Wallace, Hughes, & Franks, 2002). It has been reasoned that these principles may reflect the reality of team sports (Walter et al., 2007), in which each player's performance denotes a delicate interplay between their individual actions and the team's behaviours as a whole.

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In this vein, Social Network Analysis (SNA) emerges as a powerful tool to study systemic behaviour (e.g., analysis of its topological conformations), devoting particular attention to the relationships established within the system (Quatman & Chelladurai, 2008). As has been stated (Pow, Gayen, Elliott, & Raeside, 2012), SNA maps assist us in understanding the interactions within a group, namely the links between different players and the flow of information in the system. This method has been used in various fields of research including sport (e.g., Cotta, Mora, Merelo, & Merelo-Molina, 2013; Fransen et al., 2015), usually to expose the relationships between different elements (i.e., persons) of a given system.

Regardless, SNA emerges from graph theory, indicating that it is possible to analyse the interactions between any given set of variables (Lusher, 2010). Therefore, this instrument might be used to provide further insights regarding the logic behind performance in different sports (Bourbousson, 2010). Specifically, it is possible to use SNA to gather topologic information of sets of performance variables (e.g., game actions, behavioral patterns, events, and contextual cues, among others) in order to produce a systemic mapping of the game and its sub-sets (Lusher, Robins, & Kremer, 2010). This, in itself, will provide useful qualitative information, which is complemented by quantitative data pertaining the established relationships (e.g., node centrality measures and density, the strength of edges, and the detection of cliques, among others).

Nonetheless, most match analyses still tend to be compartmentalized and use a marked analytical approach, avoiding a systemic approach, perhaps due to its complexity. In the case of volleyball, some game variables are commonly studied: type and efficacy of the serve (Quiroga et al., 2010); quality of serve-reception (Afonso, Moraes, Mesquita, Marcelino, & Duarte, 2009); setting zone and quality (Afonso, Mesquita, Marcelino, & Silva, 2010); efficacy of the attack (based on zone attack tempo) (Araújo et al., 2011). Volleyball is usually considered to encompass five different game complexes (Ks), which are the equivalents to the concept of the sub-system. According to Hileno and Buscà (2012), volleyball can be divided into six functional and partially independent game complexes: K0 (serve), KI (side-out, including serve-reception, set, and attack); KII (side-out transition, block, dig, set and attack immediately after de side-out); KIII (transition of transitions, including the same items as KII but after another transition); KIV (attack-coverage, analyzing) and KV (freeball transition, transition without attack of the opposite team). Most authors include the K0 in the KII, due to their close functional relationships and tactical unity (e.g., Costa, Afonso, Brant, & Mesquita, 2012), but here we kept them separated as we intended to analyse the sequential paths of the game actions. How these distinct game complexes interact is scarcely known and, to our knowledge, has not been investigated. Certainly, their relationships have not been explored using SNA.

Therefore, the aim of the present study was to analyse the systemic and sub-systemic relationships (both qualitative and quantitative) in a competitive sport context using Social Network Analysis, focusing on relationships between game actions instead of on relationships between players. The specific case of high-level men's volleyball game was considered. The Ethics Committee at the Centre of Research, Education, Innovation and Intervention in Sport of the University of Porto provided institutional approval for this study.

## Methods

Eight matches from the Fédération Internationale de Volleyball (FIVB) World Cup 2015 were analysed. This highly prestigious competition is held once every four years; from this tournament, the two best-classified teams gained direct qualification to the 2016 Olympic Games in Rio. Five teams from the top six placed in the FIVB World Rankings were analysed (Poland, 2nd; Russia, 3rd; USA, 4th; Italy, 5th; and Argentina, 6th). Brazil (the number 1 in the ranking) did not participate in this tournament since it was already qualified for the Olympic Games, as the team of the host country. A total of 1,209 rallies were observed, corresponding to 27 sets.

The videos were acquired in the public domain from Youtube.com, and all had a back view of the court. Data collection was accomplished using Microsoft® Excel® 2015 and later analysed using IBM® SPSS® Statistics for Windows (Version 21, E.U.A.). The SNA were performed using Gephi© 0.8.2-beta (Version 10.10.3, France). The observers had been previously trained in order to attain proficiency and consistency in coding the data. For training purposes, each observer analysed a minimum of eight matches from different high-level competitions (men and women). Inter-observer reliability was established with Cohen's Kappa above 0.80 for all the considered variables.

The game complexes included KO (Serve), KI (Side-out), KII (Side-out transition), and KIII (Transition) (Costa et al., 2012). Although K0 is usually included in KII, we analysed it independently to better provide a perceptible sequential analysis of the game actions. Two variables were considered in K0: Serve Zone, following the official FIVB rules which divide the court into six different zones (1, 6 and 5 in the back row, as servers are behind one of these three zones), and Serve Type (jump, jump-float or standing) (Quiroga et al., 2010).

In KI, the following variables were analysed: (a) Reception Zone (the six official volleyball zones); (b) Setting Zone, which was evaluated based on the options available to the setter ("A" if the setter had all options available, "B" if the setter could still use quick plays and use the middle-attacker, but some attack combinations were not possible, and "C" when the setter could not use quick attacks); (c) Attack Tempo (based on Afonso & Mesquita (2007) and Costa et al. (2012)): 1 - the attacker was in the air or performed one step after the set; 2 -

the attacker performed two steps after the set; 3 - the attacker performed three or more steps after the set); and (d) Attack Zone, according to the FIVB's rules. Complexes II and III also made use of Setting Zone, Attack Tempo, and Attack Zone, but further presented specific variables: Block Opposition, which was analysed according to the number of blockers facing the attack (from 0 blockers to 3 blockers), and Defense Zone, which was evaluated as the zone where the dig occurred (official volleyball zones adding "others", outside the field). When any variable did not occur it was registered as Not Occurring (NO).

SNA was used; specifically, eigenvector centralities were calculated for each node. An inherent concept of Eigenvector centrality is the idea that each node is more central if it is connected with central nodes. The centrality of each depends not only on the number of connections but also of their characteristics. (Bonacich, 2007)

For the purposes of inter-observer reliability testing, 366 (30%) of rallies were analysed by an independent observer (who was an experienced coach and researcher), which is well above the 10% suggested by Tabachnick and Fidell (2000). Values of Cohen's Kappa ranged between 0.76 and 1, above the reference value of 0.75 suggested by the specialized literature (Fleiss 2003).

## Results

A topological mapping of the interactions through calculation of Eigenvector centralities is presented in Figure 1.

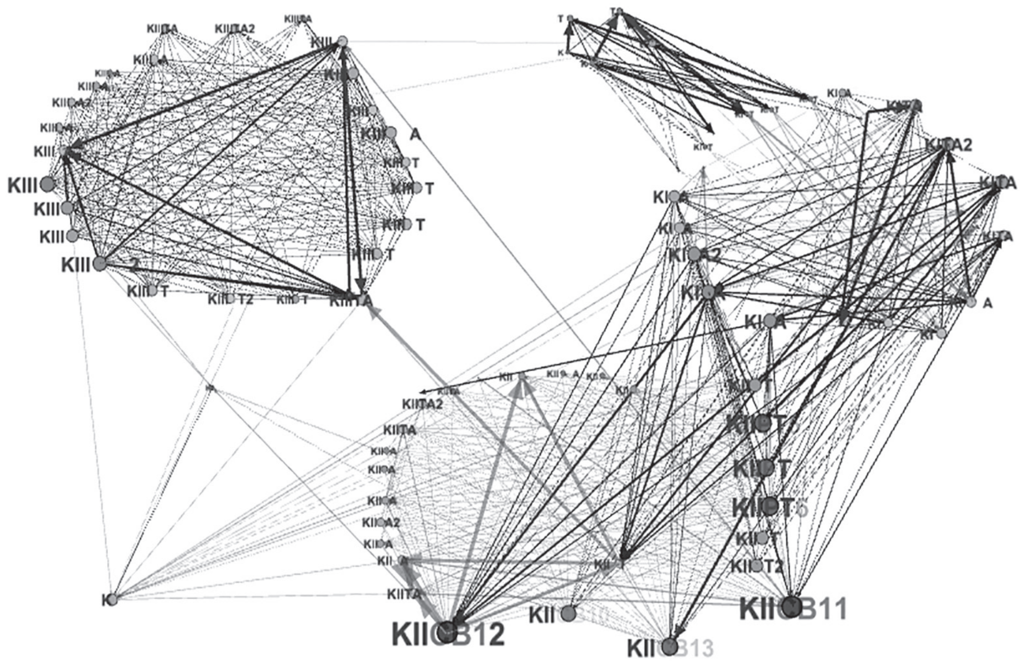

FIGURE 1 A topological mapping of the interactions through calculation of eigenvector centralities

As seen in Table 1, there were no Standing Serves, and the least used Serve Zone was 5 (0.04). There were no apparent differences between jump-float and jump serve, and the same was observed for Serve Zones 1 and 6 (0.05).

TABLE 1 Eigenvector values for Complex 0

| | Serve (K0) | | | |
|---|---|---|---|---|
| **Serve type (K0ST)** | Jump (K0STJ) | Jump-float (K0STJF) | Standing (K0STF) | **Range** |
| | 0.06 | 0.06 | - | 0.06-0.06 |
| **Serve Zone (K0SZ)** | ServZ1 (K0SZ1) | ServZ5 (K0SZ5) | ServZ6 (K0SZ6) | **Range** |
| | 0.05 | 0.04 | 0.05 | 0.04-0.05 |

With respect to KI or side-out (Table 2), all reception zones presented similar eigenvector values (0.08-0.09), with Zone 4 being the exception. Setting Zones A and B obtained the superior eigenvector values (0.39 and 0.38, respectively) when compared to Zone C (0.29). The attack zone with the highest value in side-out was 4 (0.73), followed by Zones 3 and 2 (0.69). Attack Tempos 2 and 3 predominated (0.75).

In KII (side-out transition), the double block had the highest value (1.00), followed by the single block (0.98), with triple blocks (0.81) and no opposition (0.78) being less central in the network. The vast majority of attacks were intercepted in the backcourt defensive zones, with frontcourt defensive zones being less central.

TABLE 2 Eigenvector values for Complex I

| Side-Out (KI) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Reception Zone (KIRZ)** | RZ 1 (KIRZ1) | RZ 2 (KIRZ2) | RZ 3 (KIRZ3) | RZ 4 (KIRZ4) | RZ 5 (KIRZ5) | RZ 6 (KIRZ6) | RZ Not Occurring (KIRZNO) | **Range** |
| | 0.09 | 0.08 | 0.09 | 0.06 | 0.09 | 0.09 | 0.02 | 0.02-0.09 |
| **Setting Zone (KISZ)** | SZ A (KISZA) | SZ B (KISZB) | SZ C (KISZC) | SZ Not Occurring (KISZNO) | **Range** | | | |
| | 0.39 | 0.38 | 0.29 | 0.04 | 0.04-0.39 | | | |
| **Attack Zone (KIAZ)** | AZ 1 (KIAZ1) | AZ 2 (KIAZ2) | AZ 3 (KIAZ3) | AZ 4 (KIAZ4) | AZ 5 (KIAZ5) | A Z 6 (KIAZ6) | AZ Not Occurring (KIAZNO) | **Range** |
| | 0.64 | 0.69 | 0.69 | 0.73 | 0.38 | 0.55 | 0.06 | 0.06-0.73 |
| **Attack Tempo (KIAT)** | AT1 (KIAT01) | AT 2 (KIAT2) | AT 3 (KIAT3) | AT Not Occurring (KIATNO) | **Range** | | | |
| | 0.63 | 0.75 | 0.75 | 0.60 | 0.60-0.75 | | | |

Differently from what had succeeded in KI, the attack in KII was mostly built from setting Zone C (0.45). Attack Zone 2 was predominant (0.54), closely followed by Zone 4 (0.51) and Zone 1 (0.50), but plays where an attack could not be built were also central (0.50). Similarly to KI, Attack Tempos 3 and 2 predominated (0.56).

In KIII, the triple block surpasses (0.39) double block (0.38) and single block (0.36). Results for defensive zones were similar to those obtained in KII. Contrary to KII, however, setting Zone A (0.35) again surpassed the centrality values of Zones B and C, as had occurred in KI. Attack Zones 4 (0.30), 1 and 2 (0.28) remained central nodes in the network. Again, Attack Tempos 2 and 3 (0.27 and 0.25) presented superior eigenvector values with respect to Tempo 1.

TABLE 3 Eigenvector values for Complex II

| *Side-out transition (KII)* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Number of blockers (KIINB)** | Triple (KIINB3) | Double (KIINB2) | Single (KIINB1) | No block (KIINB0) | **Range** | | | | |
| | 0.81 | 1.00 | 0.98 | 0.78 | 0.78 – 1.00 | | | | |
| **Defense Zone (KIIDZ)** | DZ 1 (KIIDZ1) | DZ 2 (KIIDZ2) | DZ 3 (KIIDZ3) | DZ 4 (KIIDZ4) | DZ 5 (KIIDZ5) | DZ 6 (KIIDZ6) | Other (KIIDFO) | DZ Not Occurring (KIIDZNO) | **Range** |
| | 0.86 | 0.67 | 0.67 | 0.66 | 0.89 | 0.91 | 0.04 | 0.49 | 0.04 – 0.89 |
| **Setting Zone (KIISZ)** | SZ A (KIISZA) | SZ B (KIISZB) | SZ C (KIISZC) | SZ Not Occurring (KIISZNO) | **Range** | | | | |
| | 0.41 | 0.38 | 0.45 | 0.43 | 0.38 – 0.45 | | | | |
| **Attack Zone (KIIAZ)** | AZ 1 (KIIAZ1) | AZ 2 (KIIAZ2) | AZ 3 (KIIAZ3) | AZ 4 (KIIAZ4) | AZ 6 (KIIAZ6) | AZ Not Occurring (KIIAZNO) | **Range** | | |
| | 0.50 | 0.54 | 0.42 | 0.51 | 0.42 | 0.50 | 0.42 – 0.54 | | |
| **Attack Tempo (KIIAT)** | AT 1 (KIIAT01) | AT2 (KIIAT2) | AT 3 (KIIAT3) | AT Not Occurring (KIIATNO) | **Range** | | | | |
| | 0.36 | 0.56 | 0.56 | 0.53 | 0.36 – 0.53 | | | | |

While the K0 always links to KI, by definition the three remaining game complexes (I, II, and III) may originate distinct events. In this case, KI never originated KIV, i.e., there were no plays starting with attack coverage after KI. However, some missed receptions and settings did originate KV.

## Discussion

Performance analysis is a powerful method for understanding the complexities, behaviours, and patterns in the game (Travassos, Davids, Araújo, & Esteves, 2013). This kind of information helps coaches in designing training processes that more closely follow the demands of competition (Ericsson, 2003). As team sports, in particular, seem to behave as dynamic systems, systemic analyses are paramount to better frame performance (Walter et al., 2007). In this vein, we applied SNA to high-level men's volleyball. Specifically, eigenvector centrality was calculated for each node, in order to understand the importance of each game action in overall performance as well as the interaction between them. Four game complexes were analysed: K0 (Serve); KI (Side-out); KII (Side-out transition) and KIII (Transition).

Results showed that the standing serve was rarely used, possibly because it tends to be less effective than other serve techniques. Nevertheless, standing serve could be an option to lower the jump frequency in the matches and create a disturbance in game patterns, especially if used as a surprise factor in certain key moments. The jump serve presented a high eigenvector centrality value, in accordance with the role it has in men's volleyball (Costa et al., 2012; Manzanares & Ortega, 2009; Palao, 2009), but this value was not superior to that presented by the jump-float, such serves in men's volleyball being associated with low risk but very low chance to score a point (Palao, 2009). The findings also showed that most of the players chose to serve in their zone of responsibility of defence (i.e., setters and opposites in Z1, outside-hitters in Z6, and middle-blockers in Z5). This seems logical, as the paths from serve to defensive positions are shortest, but may reduce variability and thus make the serve more predictable. Players could benefit from changing their serve zone in specific moments, introducing some randomness in order to imbalance the opponent. Furthermore, the serve rarely targeted Zone 4, even though this could disrupt the outside hitter's attack pattern (Afonso et al., 2010; Lithio & Webb, 2006).

TABLE 4 Eigenvector values for Complex III

| | ***Transition (KIII)*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Number of blockers (KIIINB)** | Triple (KIIINB3) | Double (KIIINB2) | Single (KIIINB1) | No block (KIIINB0) | | | | | **Range** |
| | 0.39 | 0.38 | 0.36 | 0.33 | | | | | 0.33 – 0.39 |
| **Defence Zone (KIIIDZ)** | DZ 1 (KIIIDZ1) | DZ 2 (KIIIDZ2) | DZ3 (KIIIDZ3) | DZ 4 (KIIIDZ4) | DZ 5 (KIIIDZ5) | DZ 6 (KIIIDZ6) | Other Zone (KIIIDFO) | DZ Not Occurring (KIIIDZNO) | **Range** |
| | 0.34 | 0.29 | 0.33 | 0.24 | 0.33 | 0.33 | 0.28 | 0.15 | 0.15 – 0.34 |
| **Setting Zone (KIIISZ)** | SZ A (KIIISZA) | SZ B (KIIISZB) | SZ C (KIIISZC) | SZ Not Occurring (KIIISZNO) | | | | | **Range** |
| | 0.35 | 0.29 | 0.33 | 0.32 | | | | | 0.29 – 0.35 |
| **Attack Zone (KIIIAZ)** | AZ 1 (KIIIAZ1) | AZ 2 (KIIIAZ2) | AZ 3 (KIIIAZ3) | AZ 4 (KIIIAZ4) | AZ 5 (KIIIAZ5) | AZ6 (KIIIAZ6) | Not Occurring (KIIIAZNO) | | **Range** |
| | 0.28 | 0.28 | 0.25 | 0.30 | 0.05 | 0.20 | 0.28 | | 0.05 – 0.28 |
| **Attack Tempo (KIIIAT)** | AT 1 (KIIIAT01) | AT 2 (KIIIAT2) | AT 3 (KIIIAT3) | AT Not Occurring (KIIIATNO) | | | | | **Range** |
| | 0.21 | 0.27 | 0.25 | 0.36 | | | | | 0.21 – 0.36 |

As for KI (side-out), teams played most often in-system, as the quality of the first contact was such that SZA presented the highest centrality values, as had also been observed by Bergeles and Nikolaidou (2011), having been closely followed by SZB. Despite optimal or near-optimal conditions for attack being the norm in this game complex, the attack options still largely promoted Zone 4 and Tempo 1 was the less central node. According to Costa et al. (2011) and Afonso et al. (2010), this reduces the chance of scoring a point. This has

TABLE 5 Weight values for Complexes IV and KV

| | **Categories** | **KIV (Range)** | **KV (Range)** |
|---|---|---|---|
| **Side-out (KI)** | KIRZ | | 1 – 20 |
| | KISZ | | 1 – 66 |
| | KIAZ | | 1 – 3 |
| | KIAT | | 0 |
| **Side-out Transition (KII)** | KIINB | 17-74 | |
| | KIIDZ | | 1 – 8 |
| | KIISZ | | 2 – 17 |
| | KIIAZ | | 1 |
| | KIIAT | | 1 |
| **Transition (KIII)** | KIIINB | 16-38 | |
| | KIIIDZ | | 1 – 5 |
| | KIIISZ | | 1 – 12 |
| | KIIIAZ | | 1 |
| | KIIIAT | | 1 |

practical implications for volleyball practices, as teams use slower attack tempos and reduced variation in attack zone despite having ideal conditions for doing so. Low-risk strategies seem to have been privileged, and it would be interesting to explore further why this is happening, as well as to attempt to understand what would change in the game dynamics if higher-risk strategies were to be applied.

Accordingly, teams playing in KII were able to mount double blocks more often than single blocks, thus building a strong defensive wall, in agreement with previous research (Afonso & Mesquita, 2011; Afonso, Mesquita, & Palao, 2005). Nevertheless, teams spent most of the time playing off-system, as SZC was clearly predominant, in line with the conclusions of Mesquita and Graça (2002). Therefore, even if KI attacks privileged safety over speed and variation, they managed to deliver an effective offense, and double blocks were not capable of maintaining the superior centrality of SZA and SZB over SZC. Expectedly, slower attacks by the extremities of the net emerged as central nodes. Overall, teams should prepare themselves to play KII in off-system conditions, instead of practicing in more structured, in-system contexts.

Contrariwise, the KIII emerged as distinct from the KII. For starters, triple block emerged as central, denoting a better opposition to the attack. Consequently, SZA was again predominant. Nonetheless, slower attack tempos and the extremities of the net were once more central. Unlike KI, though, mounting a quicker offense in KIII may be more difficult due to two major factors: i) most attackers are probably just recovering from the block and may not have the time to participate in quicker attack tempos; ii) in KIII fatigue is already playing a role, thus also contributing to a small centrality of quick attack tempos. The pronounced differences between KII and KIII imply that the two types of counter-attack are qualitatively different and should be analysed separately. Unfortunately, the vast majority of research merges both into a single unit reporting the counter-attack (e.g., Costa et al., 2012; Laporta, Nikolaidis, Thomas, & Afonso, 2015), although there is at least one exception (see Sánchez-Moreno, Marcelino, Mesquita, & Ureña, 2015) consider such functional differences. Finally, our data highlighted the fact that KI never originated KIV, i.e., there were no plays of attack coverage deriving from the side-out.

Overall, this study showed that gameplay under in- or off-system conditions varies depending on the game complex that is being analyzed. Specifically, KI offers volleyball teams greater possibilities of playing in-system, but a still below-expected variability in attack organization was observed. In KII, off-system conditions predominate, and such logic should be replicated in training sessions to better prepare athletes for playing under far-from-ideal conditions. Also of note, significant differences have been established between the KII and KIII, meaning that the distinction of side-out transition and transition is not pedantic, but denotes two distinct game complexes, each with its own functional dynamics. Such accentuated differences should direct researchers against grouping the two types of transition or counter-attack in the same category.

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