



# Sequencing of game complexes in women's volleyball: are there differences according to the set played?

original paper

© Wrocław University of Health and Sport Sciences

DOI: <https://doi.org/10.5114/hm/194773>

PEDRO HENRIQUE CAVALCANTE VIEIRA<sup>1</sup>, LORENZO LAPORTA<sup>2</sup>,  
GUSTAVO FERREIRA PEDROSA<sup>2</sup>, AUGUSTO FARIA DE PAULA SANTANA<sup>1</sup>,  
AURO BARREIROS FREIRE<sup>3</sup>, CRISLAINE COUTO RANGEL<sup>4</sup>,  
CLAUDIO ANDRE BARBOSA DE LIRA<sup>5</sup>, FILIPE MANUEL CLEMENTE<sup>5,6,7</sup>,  
THIAGO JOSÉ LEONARDI<sup>8</sup>, GUSTAVO DE CONTI TEIXEIRA COSTA<sup>1</sup>

<sup>1</sup> Universidade Federal de Goiás, Goiânia, Brasil

<sup>2</sup> Universidade Federal de Santa Maria, Santa Maria, Brasil

<sup>3</sup> Instituto Federal de Minas Gerais, Belo Horizonte, Brasil

<sup>4</sup> Universidade Federal de Minas Gerais, Belo Horizonte, Brasil

<sup>5</sup> Instituto Politécnico de Viana do Castelo, Escola Superior de Desporto e Lazer, Melgaço, Portugal

<sup>6</sup> Gdansk University of Physical Education and Sport, Gdańsk, Poland

<sup>7</sup> Sport Physical Activity and Health Research and Innovation Center, Viana do Castelo, Portugal

<sup>8</sup> Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil

## ABSTRACT

**Purpose.** The objective of the present manuscript was to analyse the flow of play in high-level women's volleyball by sequencing game complexes per set.

**Methods.** The sample analysed 135 matches played in the 2021/2022 Brazilian Women's Superliga, with the number of matches analysed ranging from 14 and 25 matches for all teams participating in the championship. Eigenvector Centrality and Social Network Analysis conducted the connectivity and specificity of relationships as, and inferential analysis was performed using the chi-square test with a Monte Carlo correction.

**Results.** The results showed that the highest eigenvalues were for the continuity effect, except for complex 0. Regarding the continuity effect, the eigenvalues in the first four sets were higher for complexes III, IV, and V. In the fifth set, the highest eigenvalues were close between complexes II, III, IV, and V for the continuity effect. Furthermore, the results indicated that there was no association between the sequencing of game complexes and the set played ( $\chi^2 = 2470.01$  and  $\phi = 0.34$ ,  $p = 0.272$ ), nor between the number of complexes and the set played ( $\chi^2 = 17.63$  and  $\phi = 0.03$ ,  $p = 0.346$ ).

**Conclusions.** In conclusion, women's volleyball presents gameplay strategies to sustain play, promoting game continuity, regardless of the set played. The number of game complexes required to secure a point varies between two and three game complexes. Coaches should consider the dynamics in women's volleyball matches, preparing teams for less risky and more continuous play.

**Key words:** performance analysis, attack, counter-attack, offensive structuring

## Introduction

The approach to sports games involves analysing performance parameters to optimise decision-making by players and coaches. Game analysis is the tool used to understand critical periods of the game's phases during training and competition [1–4]. In this context, this

tool enables the analysis and interpretation of teams during different moments and phases of games, identifying factors sensitive to team performance [5, 6]. Therefore, as sports evolve in offensive and defensive strategies, it becomes necessary to obtain information about game patterns so that decision-making can be adjusted to the demands of the teams [7–9].

*Correspondence address:* Filipe Manuel Clemente, Instituto Politécnico de Viana do Castelo, Escola Superior de Desporto e Lazer, 4900-347 Viana do Castelo, Portugal, e-mail: [filipe.clemente5@gmail.com](mailto:filipe.clemente5@gmail.com); <https://orcid.org/0000-0001-9813-2842>

Received: August 09, 2024

Accepted for publication: October 16, 2024

*Citation:* Vieira PHC, Laporta L, Pedrosa GF, Santana AFP, Freire AB, Rangel CC, Lira CAB, Clemente FM, Leonardi TJ, Costa GCT. Sequencing of game complexes in women's volleyball: are there differences according to the set played?. Hum Mov. 2024;25(4):96–104; doi: <https://doi.org/10.5114/hm/194773>.

When considering volleyball, the subject of this research, it was observed that games can be divided into functional phases known as game complexes (K's) [5, 10, 11]. Based on traditional and fundamental knowledge of this sport, Complex I is identified as comprising reception, setting, and attack and Complex II includes serve, block, defence, and counter-attack [10]. However, with the need to better understand all phases of the game and the construction of the attack from different offensive structuring conditions, increasing the understanding of offensive constructions in counter-attacks, the game was sequenced into the following complexes: (a) Complex 0 (K0): consisting of the serve; (b) Complex I (KI): reception, setting, and attack; (c) Complex II (KII): composed of the counter-attack following the defence of the opponent's attack; (d) Complex III (KIII): defined as the counter-attack following the opponent's counter-attack; (e) Complex IV (KIV): counter-attack following the attack coverage; (f) Complex V (KV): counter-attack following freeballs [5, 11].

Understanding volleyball through game complexes allows for the identification of team behaviour patterns according to the start of the offensive construction (e.g., from reception or defence), as well as according to the game conditions that may occur in the system, that is, in ideal conditions for offensive construction, or out system with limited conditions for offensive construction [5, 12]. In this context, research on men's and women's volleyball has shown that men's teams score more attack points after reception (KI) [8, 13], likely due to greater ball control that occurs after reception, allowing for better offensive structuring [4, 14, 15]. On the other hand, in women's volleyball, a sustaining game is observed, characterised by more attacks after defences, suggesting that slower sets and less powerful attacks in the offensive phase allow for better defensive structuring and a higher occurrence of counter-attacks [16, 17].

Game analysis in volleyball is mainly conducted through the analysis of game actions, considering a specific play complex [6, 15, 18], complicating the game's understanding. In this context, there is limited information about the transitions between complexes that occur more frequently to support training in the sport according to the level of competition [11, 12, 19]. Recent research in women's volleyball has used Social Network Analysis (SNA) to provide a relative understanding of the importance and behaviour among game complexes [20, 21], has shown that K0 was the most frequent, followed by KI from receptions that allowed organised attacks, and KII which did not allow continuity of play [5, 10]. When considering Spanish women's

volleyball, sequences such as K0-KI-KII, K0-KI-KIV, and K0-KI-KV are more likely to occur [10], whereas in Brazilian volleyball, K0-KI, K0-KI-KII are more common [5]. Despite this research on game complexes in women's volleyball, it is necessary to consider the sample size, as only seven games were analysed in both studies, suggesting that the small samples indicate a specific game pattern to a limited number of volleyball teams.

Given the above, recognising differences in the type of game played between men and women and the lack of studies on women's volleyball, it is important to identify occurrence patterns that specify the type of game played in women's volleyball and each set. This enables the planning of training sessions that are adjusted to the reality of the game, as it is not possible to extrapolate research results from men's volleyball to women's due to considerable differences in the type of game played [16, 17]. Therefore, this study aimed to analyse the game flow in high-level women's volleyball by sequencing game complexes per set. The hypotheses of the present study were: I – the eigenvector centrality values will be higher in Complexes 0, I, and II, regardless of the set played; II – the sequences of K0 with continuity effect and KI with point effect or K0 with continuity effect, KI with continuity effect, and KII with point or error effect will be the most recurrent, regardless of the set played; and III – there will be no difference in the number of game complexes required to obtain the point between sets.

## Material and methods

### Sample

This study's robustness and differential included analysis of all the teams that participated in the 2021/2022 Brazilian Women's Superliga, totalling 135 out of the 148 matches played (13 matches were excluded from the sample due to a lack of access to the games). Between 14 and 25 matches were analysed for each team. The Brazilian Women's Volleyball Superliga was selected for analysis due to its relevance, as Brazil ranks among the top 3 teams in the world [22].

### Data collection

All matches were filmed from above the court using a Sony® high-definition camera (1080p) positioned approximately 7–9 m behind the end line of the court and five metres above ground level. To analyse the games, a physical education professional with over ten years of

experience in volleyball performance analysis trained one master’s student and two undergraduate students. All had experience as volleyball athletes. For reliability testing, 15 matches were reanalysed, exceeding the 10% reference value [23]. Cohen’s Kappa values for intra-observer reliability ranged from 0.90 to 0.99, with standard errors of 0.03 and 0.01, respectively. For inter-observer analysis, the values ranged from 0.95 to 1, with a standard error of 0.02. These values are above the recommended threshold of 0.75 [24].

Variables

**Set played:** The set played was considered, with the first four sets ending when a team reaches 25 points, provided there is at least a two-point difference from the opposing team; otherwise, the set ends after the 25<sup>th</sup> point with a two-point difference. The fifth set ends when a team reaches 15 points, requiring at least a two-point difference from the opposing team; otherwise, the set ends after the 15<sup>th</sup> point with a two-point difference. **Game complex:** For the analysis of game complexes, K0, KI, KII, KIII, KIV, and KV were considered [5, 10]. In KV, freeballs and downballs were included due to their similarities in offensive construction and reduced occurrences. The flow and possible sequences of game complexes are illustrated in Figure 1.

**Complex effect:** This variable considered the effect of the attack at the end of each play complex, classifying it as an error (0), attack block (1), continuity (2), or

point (3) [25, 26]. The sequence of game complexes within each rally and the attack’s effect was recorded. It is noted that serving actions were classified similarly to attacks, except for blocking, as by rule, serves cannot be blocked in volleyball.

Statistical analysis

The data were recorded in a Microsoft Excel 2020 spreadsheet for data quality control. The SNA was conducted using Gephi 0.8.2-beta software for Mac (version 10.10.3, France). SNA was employed because this statistical procedure considers the connectivity and specificity of relationships among all contextual variables, providing a comprehensive view of the type of game played. For data analysis, SNA was used to create a network that related all sequences of game complexes by set, considering undirected nodes, allowing observation of how game complexes connect based on their effects. Eigenvector centrality was utilised, as it reflects the relationship among game complexes, based on the understanding that a node has higher centrality when it is connected to more central nodes, with a centrality value ranging from 0 to 1 [27, 28]. Therefore, node centrality depends on adjacent nodes and their interaction characteristics [19]. To visually highlight the magnitude of each node’s eigenvector values, the font size of each node was adjusted accordingly. The graph was organised using the Fruchterman-Reingold layout (area 100000) [29].

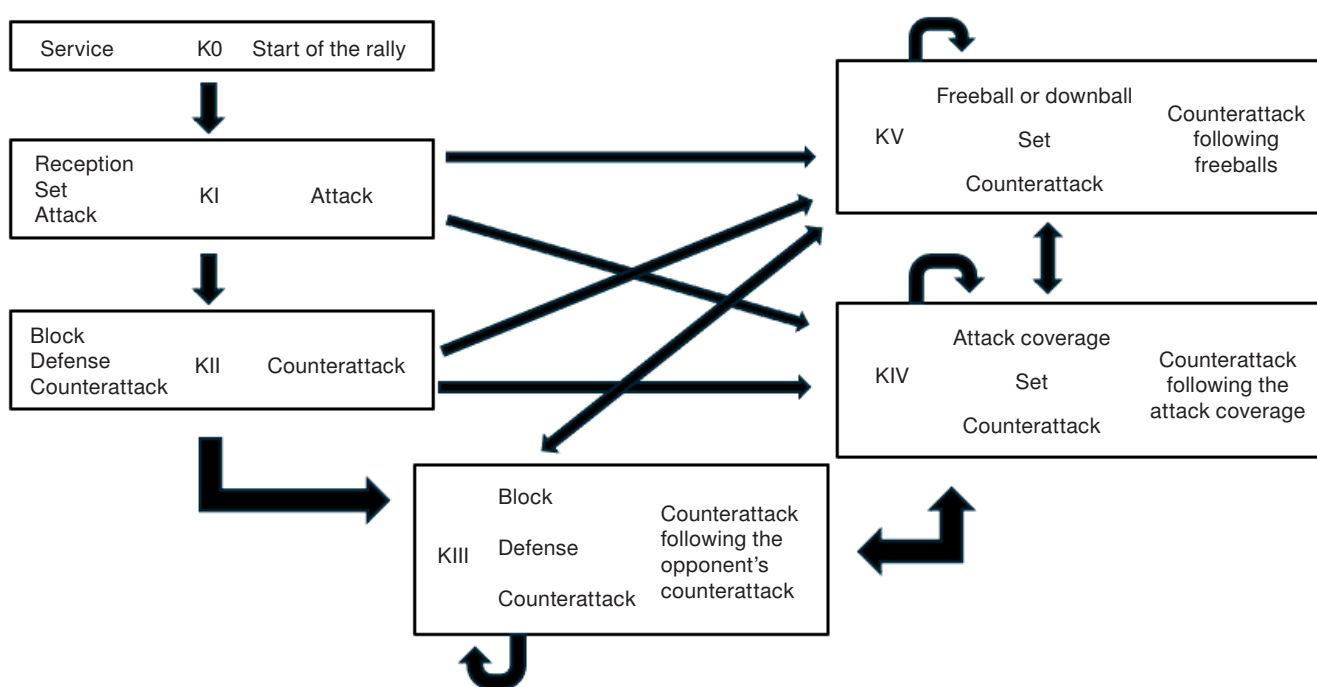


Figure 1. Flow of play and possible sequences of game complexes in volleyball

In addition to eigenvector analysis, inferential analysis was performed using the chi-square test with Monte Carlo correction when less than 20% of the cells had values less than 5, to verify the association between study variables according to the set played. Residual adjustments were calculated to identify which cells showed statistical significance in explaining the relationship between two variables. In data treatment, the significance level was set at 5% ( $p \leq 0.05$ ), and the effect size was calculated using phi ( $\phi$ ) (small:  $V < 0.1$ , moderate:  $0.1 \leq V < 0.3$ , large:  $V \geq 0.3$ ). The data were analysed using SPSS (Statistical Package for the Social Sciences) version 29.0 for MacOS.

**Results**

The SNA resulted in a graph identifying the connections between the game complexes and their effects per set (Figure 2). Table 1 presents the eigenvector values.

As observed in Table 1 and Figure 2, the highest eigenvector values were associated with the effect of continuity, except for K0. In the first four sets, the highest eigenvector values were for Complexes III, IV, and V for the continuity effect. In the fifth set, the highest eigenvector values were similar among Complexes II, III, IV, and V for the continuity effect.

Considering the association between sequencing and the set played, 608 different sequencing types were observed. The results showed no association between the sequencing of game complexes and the set played ( $\chi^2 = 2470.01, \phi = 0.34, p = 0.272$ ). The most recurrent sequences were: K0-2-KI-3 (33.8%), K0-0 (10.3%), K0-2-KI-0 (7.1%), K0-2-KI-2-KII-3 (7.1%), K0-2-KI-1 (6.9%), and K0-3 (4.5%). The analysis of the complexes showed no association between the number of complexes and the set played ( $\chi^2 = 17.63, \phi = 0.03, p = 0.346$ ), as shown in Table 2.

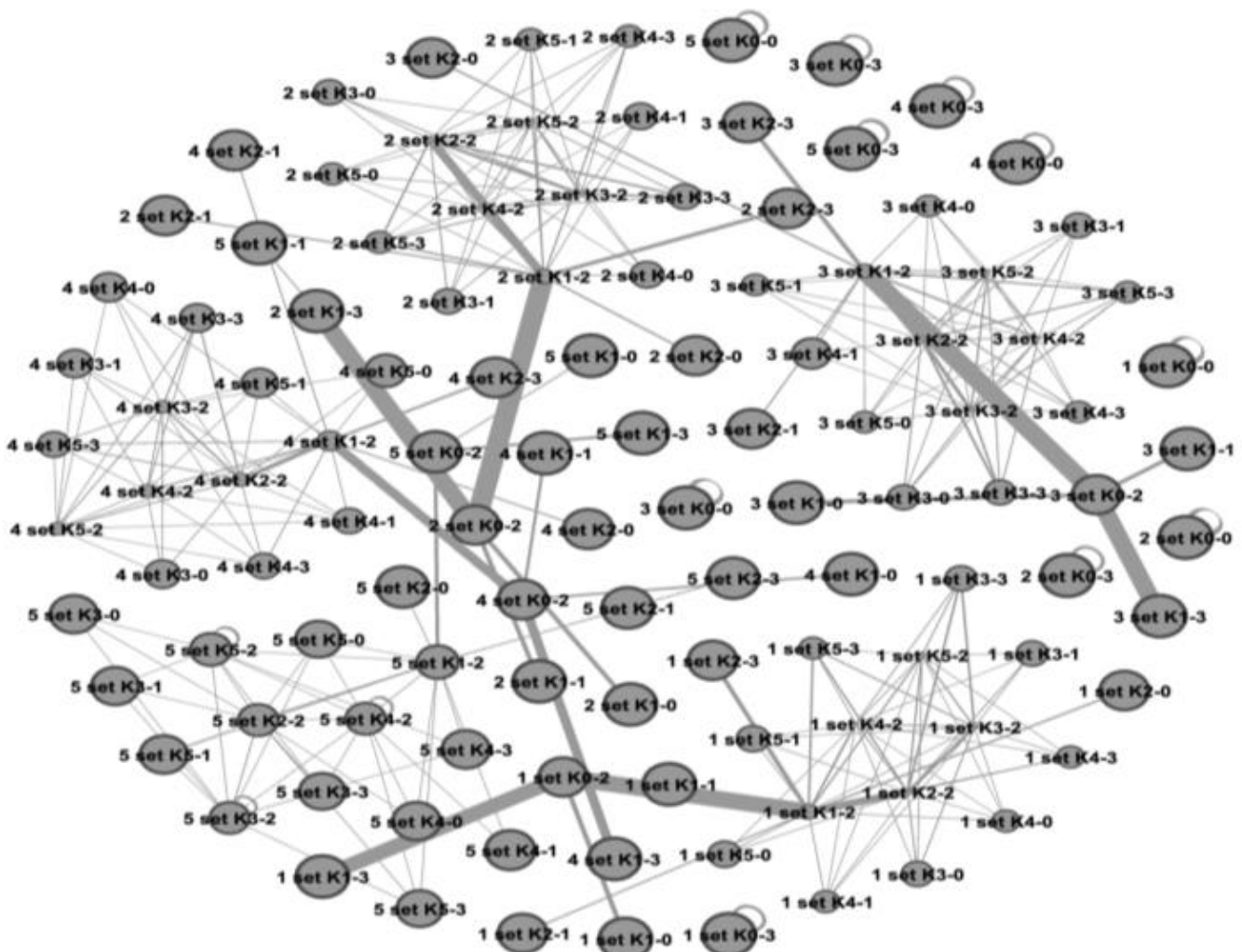


Figure 2. Graph of complex sequencing based on eigenvector values. Each node displays in its name the set, the complex, and the effect that each one represents. Thus, “2 set K3-0” indicates that K3 is associated with the effect of continuity in the second set



Table 1. Eigenvector values for game complexes per set

1 <sup>st</sup> set											
Complex 0		Complex I		Complex II		Complex III		Complex IV		Complex V	
K0-0	0.00	KI-0	0.01	KII-0	0.08	KIII-0	0.43	KIV-0	0.51	KV-0	0.41
K0-2	0.09	KI-1	0.01	KII-1	0.08	KIII-1	0.43	KIV-1	0.51	KV-1	0.41
K0-3	0.00	KI-2	0.70	KII-2	0.90	KIII-2	0.92	KIV-2	1.00	KV-2	0.90
		KI-3	0.01	KII-3	0.08	KIII-3	0.43	KIV-3	0.51	KV-3	0.51
2 <sup>nd</sup> set											
K0-0	0.00	KI-0	0.01	KII-0	0.08	KIII-0	0.43	KIV-0	0.40	KV-0	0.51
K0-2	0.09	KI-1	0.01	KII-1	0.08	KIII-1	0.43	KIV-1	0.40	KV-1	0.51
K0-3	0.00	KI-2	0.70	KII-2	0.89	KIII-2	0.91	KIV-2	0.95	KV-2	0.95
		KI-3	0.01	KII-3	0.08	KIII-3	0.43	KIV-3	0.51	KV-3	0.51
3 <sup>rd</sup> set											
K0-0	0.00	KI-0	0.01	KII-0	0.08	KIII-0	0.44	KIV-0	0.52	KV-0	0.52
K0-2	0.09	KI-1	0.01	KII-1	0.08	KIII-1	0.44	KIV-1	0.30	KV-1	0.52
K0-3	0.00	KI-2	0.71	KII-2	0.91	KIII-2	0.93	KIV-2	0.98	KV-2	0.98
		KI-3	0.01	KII-3	0.08	KIII-3	0.44	KIV-3	0.52	KV-3	0.52
4 <sup>th</sup> set											
K0-0	0.00	KI-0	0.01	KII-0	0.07	KIII-0	0.36	KIV-0	0.33	KV-0	0.25
K0-2	0.07	KI-1	0.01	KII-1	0.07	KIII-1	0.36	KIV-1	0.42	KV-1	0.33
K0-3	0.00	KI-2	0.56	KII-2	0.73	KIII-2	0.75	KIV-2	0.75	KV-2	0.75
		KI-3	0.01	KII-3	0.07	KIII-3	0.36	KIV-3	0.42	KV-3	0.42
5 <sup>th</sup> set											
K0-0	0.00	KI-0	0.01	KII-0	0.03	KIII-0	0.11	KIV-0	0.11	KV-0	0.14
K0-2	0.03	KI-1	0.01	KII-1	0.03	KIII-1	0.11	KIV-1	0.07	KV-1	0.11
K0-3	0.00	KI-2	0.22	KII-2	0.26	KIII-2	0.27	KIV-2	0.26	KV-2	0.24
		KI-3	0.01	KII-3	0.03	KIII-3	0.15	KIV-3	0.10	KV-3	0.14

The “KIII-0” indicates that KIII is associated with the effect of continuity in the second set.

**Discussion**

The present study aimed to analyse the flow of play in high-level women’s volleyball by sequencing game complexes by set. We listed three different hypotheses for the study: I – the eigenvector centrality values will be higher in Complexes 0, I, and II, regardless of the set played; II – the sequences of K0 with continuity effect and KI with point effect or K0 with continuity effect, KI with continuity effect, and KII with point or error effect will be the most recurrent, regardless of the set played; and III – there will be no difference in the number of game complexes required to obtain the point between sets.

The first hypothesis was refuted. Network analysis showed that the continuity effect presented the highest eigenvector value across all game complexes and sets analysed, with the highest eigenvector values occurring for Complexes II and III up to the third set. In the fourth

set, the highest eigenvector values were observed for Complexes III, IV, and V, and in the fifth set, the highest eigenvector values were for Complexes II, III, IV, and V for the continuity effect. These results are consistent with the literature, which demonstrated higher eigenvector values for the continuity effect in women’s volleyball game complexes, where points are associated with Complexes II, III, and IV [5, 10].

Although no studies specifically analysed game complexes per set, the higher eigenvector values for Complexes III, IV, and V in the fourth and fifth sets might be explained by mental fatigue caused by the demands of the game. Mental fatigue is characterised by a sense of tiredness and/or lack of energy after long periods of cognitive activity [30], which impairs decision-making and athletic performance [31–35]. In this context, considering that there is a sustaining game in women’s volleyball due to lower power in terminal actions such as serving and attacking [26, 36], as well

Table 2 – Association between the set played and the number of Ks

		Number of Ks					
		1	2	3	4	5 or more	total
1 <sup>st</sup> set	count	949	2810	1001	607	613	5980
	expected count	885.7	2856.2	989.1	612.8	636.2	5980.0
	% set	15.9%	47.0%	16.7%	10.2%	10.3%	100.0%
	% of Ks	29.6%	27.1%	27.9%	27.3%	26.6%	27.6%
	adjusted residuals	2.7	-1.4	0.5	-0.3	-1.1	
2 <sup>nd</sup> set	count	904	2911	995	607	663	6080
	expected count	900.5	2903.9	1005.7	623.0	646.9	6080.0
	% set	14.9%	47.9%	16.4%	10.0%	10.9%	100.0%
	% of Ks	28.2%	28.1%	27.8%	27.3%	28.8%	28.1%
	adjusted residuals	0.2	0.2	-0.4	-0.8	0.8	
3 <sup>rd</sup> set	count	881	2875	965	629	641	5991
	expected count	887.3	2861.4	990.9	613.9	637.4	5991.0
	% set	14.7%	48.0%	16.1%	10.5%	10.7%	100.0%
	% of Ks	27.4%	27.8%	26.9%	28.3%	27.8%	27.6%
	adjusted residuals	-0.3	0.4	-1.1	0.8	0.2	
4 <sup>th</sup> set	count	381	1410	492	299	310	2892
	expected count	428.3	1381.3	478.4	296.4	307.7	2892.0
	% set	13.2%	48.8%	17.0%	10.3%	10.7%	100.0%
	% of Ks	11.9%	13.6%	13.7%	13.5%	13.4%	13.3%
	adjusted residuals	-2.7	1.1	0.7	0.2	0.1	
5 <sup>th</sup> set	count	95	346	132	79	79	731
	expected count	108.3	349.1	120.9	74.9	77.8	731.0
	% set	13.0%	47.3%	18.1%	10.8%	10.8%	100.0%
	% of Ks	3.0%	3.3%	3.7%	3.6%	3.4%	3.4%
	adjusted residuals	-1.4	-0.2	1.1	0.5	0.1	
Total	count	3210	10352	3585	2221	2306	21674
	expected count	3210.0	10352.0	3585.0	2221.0	2306.0	21674.0
	% set	14.8%	47.8%	16.5%	10.2%	10.6%	100.0%
	% of Ks	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Each column represents the number of Ks played by the teams from the first to the fifth set of the match.

as a slower-paced game [26, 36, 37], it can be considered that the fatigue accumulated throughout the match can lead to poorer decision-making, consequently altering the sequence of game complexes, as indicated by the results found in this study.

The second hypothesis was refuted. Contradicting these results, a previous study analysed two matches (six sets) from the 2015 Copa de la Reina and five matches from the same competition in 2016, observing that the most frequent sequences were: K0-KI-KII, followed by K0-KI-KIV, K0-KI-KV, and K0-KI-UK [10]. They also found that Complexes II, III, and IV were more closely associated with non-continuity. In another study, Rocha et al. [6] analysed seven matches from the Women's Brazil Cup 2020, showing that 77% of the

sample had between one and four-game complexes (Table 1), suggesting that high-level women's volleyball involves more continuity actions, with positive associations between KI, KII, KIII, and KV and points. In this context, the differences observed between the findings of this study and existing literature may be due to the number of games analysed, further highlighting the differences between all the teams participating in the competition and the analysis of matches between teams with different performance levels.

The third hypothesis was confirmed. In this regard, Hileno et al. [10] observed that nearly half of the points were scored after three complexes like K0-KI-KII, K0-KI-KIV, and K0-KI-KV. In another study, Laporta et al. [5] found that sequences with two or three com-

plexes represented 65% of the sample, suggesting that women's volleyball may move toward game patterns observed in men's volleyball. Despite the limited number of studies on women's volleyball and game sequencing, the results indicate a sustaining game and continuity in play. Additionally, as discussed in the first hypothesis, it must be considered that as the number of sets increases during a match, there is greater mental fatigue [30], which reverberates in poorer athletic performance [31–35]. This, in turn, can modify the sequencing of game complexes without altering the number of complexes required to score a point.

Overall, the results show that in women's volleyball, there is an emphasis on avoiding errors at the expense of scoring points, indicating a difference in strategy compared to men's volleyball, where athletes take the risk of errors by prioritising faster sets and powerful attacks [3, 6, 38]. Likely, the type of game played is based on physical characteristics, precisely strength and power, which confer greater continuity to the game in women's volleyball [26, 36, 37]. In this regard, it should be noted that the present study analysed 90% of the matches from the 2020–2021 Women's Superliga, considering sequencing from matches between higher and lower-ranked teams. Therefore, the number of sets, type of matchup, and stage of the championship may influence the type of game played [18, 39, 40], with distinct sequencing patterns potentially arising from the specificities of the matchup.

However, it must be acknowledged that this study, like any other, has limitations. Although many matches were analysed, the confrontations between teams of different performance levels were not considered, which may reveal different sequencing patterns according to the opponent's performance level, or the players' mental fatigue, other types of psychological pressures throughout the sets, or varying strategies employed by the coaches. In this context, this research provides volleyball coaches with an understanding of the importance of training in attack or counter-attack situations from various scenarios, as sustaining play is a key aspect of offensive strategies in women's volleyball. Therefore, the training of women's teams should consider that initiating offensive construction can alter the course of game sequencing, making it necessary to consider offensive construction from less frequent conditions. For example, it may be advantageous for an attack to be deliberately directed against the block, allowing the team to rebuild the offensive phase starting from KIV.

## Conclusions

Women's volleyball features game strategies oriented towards sustaining play, promoting game continuity regardless of the set played. Additionally, the number of game complexes required to score a point ranges between two and three complexes, with over 600 distinct sequences observed in the sample analysed in this manuscript. Therefore, coaches should consider the dynamics in women's volleyball matches, preparing teams for less risky and more continuous play.

## Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee (CAAE No.: 15137319.6.0000.5083).

## Informed consent

Informed consent has been obtained from all individuals included in this study.

## Conflict of interest

The authors state no conflict of interest.

## Disclosure statement

No author has any financial interest or received any financial benefit from this research.

## Funding

This research received no external funding.

## References

- [1] Lima VDS, Rocha FBF, Diniz IB, García-de-Alcaraz A, Palao JM, Costa GCT, Mesquita I, Medeiros AIA, Batista GR. Status of match analysis research in indoor and beach volleyball: a bibliometric analysis. *Retos*. 2023;50:838–48; doi.org/10.47197/retos.v50.100039.
- [2] López E, Molina JJ, Díaz-Bento MS, Díez-Vega I. Spike performance in K1: influence of rotation and reception area on high level men's volleyball teams. *Retos*. 2023;48:213–21; doi.org/10.47197/retos.v48.93875.
- [3] Nascimento MH, Laporta L, Rocha ACR, Lira CABD, Campos MH, Pedrosa GF, Guimarães JS, Rodrigues MCJ, Leonardi TJ, Castro HO, Costa GCT. Decision making in men's high-level volleyball: analysis of the setter based on game performance. *J Phys Educ Sport*. 2023;23(3):603–12; doi: 10.7752/jpes.2023.03075.

- [4] Rocha ACR, Laporta L, Rodrigues GP, Barbosa CA, Castro HO, Costa GCT. Is it possible for the reception and the player-receiver to influence the offensive construction in volleyball? An ecological vision and Intragame procedural relationships in high-level teams. *Int J Perform Anal Sport*. 2023; 23(4):319–33; doi: 10.1080/24748668.2023.2229204.
- [5] Laporta L, Costa GCT, Fernandes LG, Pastori IA, Rocha ACR, Hileno R, Lima RF, Castro HO, Afonso J. Sequence and efficacy of game complexes in high-level women's volleyball: a novel perspective through Social Network Analysis. *Int J Sports Sci Coach*. 2023;18(3):867–73; doi: 10.1177/17479541221108.
- [6] Rocha ACR, Laporta L, Rodrigues GP, Guimarães JDS, Do Nascimento MH, Rodrigues MCJ, Leonardi TJ, de Lira CAB, Castro HO, Costa GCT. Inter e intra-variability of the best ranked teams: a network analysis in male high-level volleyball. *PLOS ONE*. 2023;18(2):e0280365; doi: 10.1371/journal.pone.0280365.
- [7] Drikos S, Barzouka K, Balasas DG, Sotiropoulos K. Effect of quality of opposition on game performance indicators in elite male volleyball. *Int J Sports Sci Coach*. 2022;17(1):169–77; doi: 10.1177/1747954121110137.
- [8] Giatsis G, Drikos S, Lola A. Analysis of match report indicators in men's volleyball Olympics and world championships (2014–2021) depending on the type of final score. *Int J Sports Sci Coach*. 2023;18(3):874–82; doi: 10.1177/174795412211086779.
- [9] Praça GM, Moreira PED, De Andrade AGP, Clemente FM, De Oliveira WB, Demétrio G. Integrating notational and positional analysis to investigate tactical behavior in offensive and defensive phases of football matches. In: *Proceedings of the Institution of Mechanical Engineers, Part P. J Sports Eng Technol*. 2022;175433712211220; doi: 10.1177/175433712211220.
- [10] Hileno R, Arasanz M, García-de-Alcaraz A. The sequencing of game complexes in women's volleyball. *Front Psychol*. 2020;11:739; doi: 10.3389/fpsyg.2020.00739.
- [11] Laporta L, Afonso J, Mesquita I. Interaction network analysis of the six game complexes in high-level volleyball through the use of Eigenvector Centrality. *PLOS ONE*. 2018;13(9):e0203348; doi: 10.1371/journal.pone.0203348.
- [12] Loureiro M, Hurst M, Valongo B, Nikolaidis P, Laporta L, Afonso J. A comprehensive mapping of high-level men's volleyball gameplay through Social Network Analysis: analysing serve, side-out, side-out transition and transition. *Monten J Sports Sci Med*. 2017;6(2):35–41; doi: 10.26773/mjssm.2017.09.005.
- [13] Silva M, Marcelino R, Lacerda D, João PV. Match analysis in volleyball: a systematic review. *Monten J Sports Sci Med*. 2016;5(1):35–46.
- [14] Martins JB, Mesquita I, Mendes A, Santos L, Afonso J. Inter-team variability in high-level women's volleyball from the perspective of Social Network Analysis: an analysis in critical game scenarios. *Int J Perform Anal Sport*. 2021;21(4):564–78; doi: 10.1080/24748668.2021.1924524.
- [15] Rocha ACR, Laporta L, Andre Barbosa De Lira C, Modenesi H, Figueiredo LS, Costa GCT. Complex I in male elite volleyball: an interactional analysis according to reception location. *Int J Perform Anal Sport*. 2022;22(1):77–89; doi: 10.1080/24748668.2021.2003961.
- [16] Drikos S, Sotiropoulos K, Gkreka S, Tsakiri M, Barzouka K. Variations in attack patterns between female and male outside hitters in top-level volleyball. *Int J Sports Sci Coach*. 2023;18(1):245–56; doi: 10.1177/17479541221107572.
- [17] Sotiropoulos K, Drikos S, Barzouka K. Variations in attack patterns between female and male opposite players in top-level volleyball. *Int J Sports Sci Coach*. 2022;17(2):400–11; doi: 10.1177/17479541211030633.
- [18] Rocha ACR, Pedrosa GF, Freire AB, Praça GM, Ugrinowitsch H, Castro HDO, et al. Analysis of the setting and predictive factors of the effect of attack according to game ecology: the case of female volleyball. *Kinesiology*. 2020;52(2):217–23.
- [19] Hurst M, Loureiro M, Valongo B, Laporta L, Afonso J. Systemic mapping of high-level women's volleyball using Social Network Analysis: the case of serve (K0), Side-out (KI), side-out transition (KII) and transition (KIII). *Int J Perform Anal Sport*. 2016;16(2):695–710; doi: 10.1080/24748668.2016.11868917.
- [20] Bai Z, Bai X. Towards Understanding the analysis, models, and future directions of sports social networks. *Complexity*. 2022;2022(1):5743825; doi: 10.1155/2022/5743825.
- [21] Wäsche H, Dickson G, Woll A, Brandes U. Social Network Analysis in sport research: an emerging paradigm. *Eur J Sport Soc*. 2017;14(2):138–65; doi: 10.1080/16138171.2017.1318198.
- [22] FIVB. FIVB Women's Volleyball World Ranking. 2024. Available from: <https://en.volleyballworld>.



- com/volleyball/world-ranking/women (accessed 09.12.2024).
- [23] Tabachnick BG, Fidell LS. *Using Multivariate Statistics*. 6<sup>th</sup> ed. Boston: Pearson Education; 2013, p. 983.
- [24] Fleiss JL, Levin B, Paik MC. *Statistical Methods for Rates and Proportions*. 3<sup>rd</sup> ed. Somerset: Wiley; 2013.
- [25] Costa GC, Caetano RCJ, Ferreira NN, Junqueira G, Afonso J, Costa RDrP, Mesquita M. Determinants of attack tactics in youth male elite volleyball. *Int J Perform Anal Sport*. 2011;11(1):96–104; doi: 10.1080/24748668.2011.11868532.
- [26] Costa G, Afonso J, Brant E, Mesquita I. Differences in game patterns between male and female youth volleyball. *Kinesiology*. 2012;44(1):60–6.
- [27] Bonacich P. Some unique properties of eigenvector centrality. *Soc Netw*. 2007;29(4):555–64; doi: 10.1016/j.socnet.2007.04.002.
- [28] Borgatti SP. Centrality and network flow. *Soc Netw*. 2005;27(1):55–71; doi: 10.1016/j.socnet.2004.11.008.
- [29] Newman MEJ. Modularity and community structure in networks. *Proc Natl Acad Sci*. 2006;103(23):8577–82; doi: 10.1073/pnas.0601602103.
- [30] Smith MR, Thompson C, Marcora SM, Skorski S, Meyer T, Coutts AJ. Mental fatigue and soccer: current knowledge and future directions. *Sports Med*. 2018;48(7):1525–32; doi: 10.1007/s40279-018-0908-2.
- [31] Badin OO, Smith MR, Conte D, Coutts AJ. Mental fatigue: impairment of technical performance in small-sided soccer games. *Int J Sports Physiol Perform*. 2016;11(8):1100–5; doi: 10.1123/ijsp.2015-0710.
- [32] Coutinho D, Gonçalves B, Wong DP, Travassos B, Coutts AJ, Sampaio J. Exploring the effects of mental and muscular fatigue in soccer players' performance. *Hum Mov Sci*. 2018;58:287–96; doi: 10.1016/j.humov.2018.03.004.
- [33] Gantois P, Caputo Ferreira ME, Lima-Junior DD, Nakamura FY, Batista GR, Fonseca FS, Fortes LS. Effects of mental fatigue on passing decision-making performance in professional soccer athletes. *Eur J Sport Sci*. 2020;20(4):534–43; doi: 10.1080/17461391.2019.1656781.
- [34] Sun H, Soh KG, Mohammadi A, Toumi Z, Zhang L, Ding C, Gao X, Tian J. Counteracting mental fatigue for athletes: a systematic review of the interventions. *BMC Psychol*. 2024;12(1):67; doi: 10.1186/s40359-023-01476-w.
- [35] Teoldo I, Dambroz F, Brito J. Performance of soccer players under acute physical fatigue: an approach based on cognitive, tactical and physical aspects. *Heliyon*. 2024;10(9):e30516; doi: 10.1016/j.heliyon.2024.e30516.
- [36] Laporta L, Medeiros A, Vargas N, Castro H, Bessa C, João P, Costa GCT, José A. Coexistence of distinct performance models in high-level women's volleyball. *J Hum Kinet*. 2021;78:161–73; doi: 10.2478/hukin-2021-0048.
- [37] Araújo CRP, Tosini L, Freire AB, Costa GDCT, Meira Jr CM. Reception-attack relation in men's and women's volleyball during the Rio 2016 Olympics. *J Phys Educ Sport*. 2020;20(Suppl 3):2008–12; doi: 10.7752/jpes.2020.s3271.
- [38] Rocha ACR, Laporta L, Modenesi H, Vancini RL, Fonseca FDS, Batista GR, Medeiros AIA, Campos MH, Dutra LN, de Lira CAB, Freire AB, Costa GCT. Setting distribution analysis in elite-level men's volleyball: an ecological approach. *Res Soc Dev*. 2021;10(1):e47710111994; doi: 10.33448/rsd-v10i1.11994.
- [39] Costa GDCT, Maia MP, Rocha ACR, Martins LR, Gemente FRF, Campos MH, Milistetd M, Freire AB. Association between effect of reception and game procedures in high-level Brazilian volleyball: the case of the women's "Superliga" champion team. *Braz J Kinesiol Hum*. 2017;19(6):663–75; doi: 10.5007/1980-0037.2017v19n6p663.
- [40] Rocha ACR, Freire AB, Martins LR, Maia MP, Guimarães JDS, Ugrinowitsch H, Castro HO, Costa GCT. Predictive factors of the attack efficacy: the case of the Brazilian women's Volleyball League champion team. *Rev Bras Cineantropom Desempenho Hum*. 2019;21:e59383; doi: 10.1590/1980-0037.2019v21e59383.