European Journal of Sport Science

ISSN: 1746-1391 (Print) 1536-7290 (Online) Journal homepage: http://www.tandfonline.com/loi/tejs20

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To cite this article: Ana Ramos, Patrícia Coutinho, Pedro Silva, Keith Davids & Isabel Mesquita (2017) How players exploit variability and regularity of game actions in female volleyball teams, European Journal of Sport Science, 17:4, 473-481, DOI: 10.1080/17461391.2016.1271459

To link to this article: https://doi.org/10.1080/17461391.2016.1271459

Published online: 09 Jan 2017.

European Journal of Sport Science, 2017
Vol. 17, No. 4, 473–481, http://dx.doi.org/10.1080/17461391.2016.1271459

Routledge
Taylor & Francis Group

ORIGINAL ARTICLE

How players exploit variability and regularity of game actions in female volleyball teams

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Abstract
Variability analysis has been used to understand how competitive constraints shape different behaviours in team sports. In this study, we analysed and compared variability of tactical performance indices in players within complex I at two different competitive levels in volleyball. We also examined whether variability was influenced by set type and period. Eight matches from the 2012 Olympics competition and from the Portuguese national league in the 2014–2015 season were analysed (1496 rallies). Variability of setting conditions, attack zone, attack tempo and block opposition was assessed using Shannon entropy measures. Magnitude-based inferences were used to analyse the practical significance of compared values of selected variables. Results showed differences between elite and national teams for all variables, which were co-adapted to the competitive constraints of set type and set periods. Elite teams exploited system stability in setting conditions and block opposition, but greater unpredictability in zone and tempo of attack. These findings suggest that uncertainty in attacking actions was a key factor that could only be achieved with greater performance stability in other game actions. Data suggested how coaches could help setters develop the capacity to play at faster tempos, diversifying attack zones, especially at critical moments in competition.

Keywords: *Performance, game analysis, team sport, dynamical systems*

Introduction

Team sports have been considered as dynamical and complex systems that are degenerate (defined as the same performance outcomes being achieved in different ways) in character signifying that a competitive environment affords a manifold of solutions to achieve the same performance outcomes (Davids, Araújo, Seifert, & Orth, 2015; Seifert, Button, & Davids, 2013). From this perspective, inherent neurobiological system degeneracy facilitates the capacity of performers to explore and exploit different perceptual-motor solutions in sport performance environments (Seifert et al., 2013). This intrinsic complexity implies that observing the subtle balance between system variability and stability of actions is essential to understand how competitive dynamical constraints may be satisfied by performers to achieve different performance outcomes in team sports (Davids & Araújo, 2005; Rhea et al., 2011). According to dynamical systems theory, adaptive variability has form and can be characterised by a highly complex and chaotic structure (Harbourne & Stergiou, 2009). A decrease or loss in adaptive variability will make a system more rigid, and increases will create more noisy and unstable behaviours (Stergiou & Decker, 2011; Stergiou, Harbourne, & Cavanaugh, 2006).

Research in individual and team sports has investigated variability in order to understand team performance under specific performance constraints. For instance, Silva, Aguiar, et al. (2014) used measures of Shannon entropy to reveal the depth of tactical roles of players in small-sided games played on fields differing in dimension. Further evidence in studies of both inherent and functional variability, some of them using entropy measures, has emerged from investigations in long jumping, triple jumping, table tennis (Davids, Savelsbergh, & Bennett, 2002), basketball (Araújo, Davids, Bennett, Button,

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& Chapman, 2004), boxing (Hristovski, Davids, & Araújo, 2006) and association football (Vilar, Araújo, Davids, & Bar-Yam, 2013). For example, Duarte et al. (2012) investigated changes in complexity of collective behaviours in professional football teams during competitive performance and found that key events (goals scored and game breaks) seemed to influence emergence of patterns in collective performance.

In the team sport of volleyball, there is a general consensus on the importance of promoting adaptive variability in some game actions to avoid predictability and to help performers to exploit different performance solutions when competitive conditions change (Silva et al., 2015). The first point of ball contact in performance (service-reception or defence) is usually directed to one specific zone, and only in the second contact (setting) can the setter introduce variability in the offensive phase, through manipulation of attack zones and tempos. This is particularly observed in complex I that comprises the actions of reception, setting and attacking (Martín & Santandreu, 2009; Mesquita, Paolo, Marcelino, & Afonso, 2012). In this complex, the setter has more time to prepare several types of offensive combinations compared to the other game complexes (i.e. related to defense and counter-attack) (Castro, Souza, & Mesquita, 2011). For that reason, complex I afford players opportunities to enhance variability of a team's tactical behaviours.

As previously reported, functional patterns of coordinated behaviour emerge through performers' interactions with each other under specific task (contextual) constraints of a competitive environment (Afonso & Mesquita, 2011; Araújo, Silva, & Davids, 2015; Hristovski et al., 2006). In volleyball, one of the most important contextual constraints identified is the set, which has been defined by Marcelino, Mesquita, and Sampaio (2010) as a 'micro-game' (i.e. important mini-game within a game). To successfully compete in a volleyball match, teams need to win three sets, in other words, the three micro games that are relatively independent of each other. The effects of a set on performance have been studied according to its temporal sequence within a competitive game (i.e. initial, intermediate and final sets), along with effects of different moments within each set (initial period, intermediate period and final period) (Marcelino et al., 2010). This is because the nature of each set can influence team tactical performance (Jorg & Wolfgang, 2007), psychologically (Males, Kerr, Thatcher, & Bellew, 2006) and physiologically (Sheppard, Gabbett, & Stanganelli, 2009).

An interesting issue concerns how volleyball teams adapt their tactical behaviours according to the contextual constraints provided by each set in competitive matches. In team games as complex adaptive systems, an increase in variability could facilitate emergence of more options, selection of functional strategies and flexibility to adapt to variations in competitive performance constraints. In line with these ideas, it is interesting to observe whether the emergence of functional variability could be delimited by the expertise level of a team. Research related to performance analysis in Volleyball reveals scarce information about performance differences between teams at different expertise levels. Indeed, most studies have typically compared performance of teams at similar competitive levels (Afonso & Mesquita, 2011). Thus, to the best of our knowledge, little is known about the role of adaptive variability on the emergence of tactical performance behaviours in volleyball teams at different expertise levels.

Therefore, the aims of this study were twofold. First, we sought to analyse and compare the variability (here defined as an indicator of unpredictability and flexibility of tactical behaviours) observed in tactical performance within complex I (setting conditions, attack zone, attack tempo and also block opposition) of volleyball teams differing in expertise levels. Second, we sought to examine whether variability of these performance indicators may have been influenced by contextual constraints of each set (e.g. non-deciding and deciding sets in competition) and of set periods (i.e. initial and final periods in a set) within a competitive game. We hypothesised that, compared to less experienced (national level (NL)) performers, more experienced (elite level (EL)) volleyball players would display: (i) greater variability of actions in zones and tempos of attack; and (ii), greater regularity in the setting conditions and block opposition. In decisional set (DS) and also during final set periods, it was expected that such differences would be exacerbated between the two groups.

Methods

Participants

In this study, we sought to study athletes in Olympic-level competition because it includes the most elite volleyball teams globally. On the other hand, convenience and purposive sampling criteria (Patton, 2002) were used to select the teams for analysis at an NL (i.e. Portuguese League). The result was that performance in eight matches from the 2012 Olympics women's volleyball competition and eight matches from the women's Portuguese 2014–2015 national league were analysed in this study. Two competitive levels were considered: an EL, which included the top eight ranked teams in the Olympic Games 2012 (Brazil, Russia, Japan, China, Korea, Italy, USA and Dominican Republic), and an NL group, including the top eight ranked teams in the Portuguese 2014–2015 national league. A total of 60 sets (30 sets in each group) and 1496 game sequences were analysed in both groups. Performance of EL participants was analysed in all matches from the quarter-finals to the final of the 2012 Olympic Games competition. Performance of the NL participants was analysed for the last three games of the top four ranked teams and the latest game of the four teams placed fifth to eighth in the league. The study protocol followed the guidelines stated in the Declaration of Helsinki and were approved by the ethics committee of the first author's institution.

Variables

In this study, we analysed *setting conditions, attack zone, attack tempo, block opposition, set type* and *set period*, because these variables are considered to characterise success in complex I performance (Afonso, Moraes, Mesquita, Marcelino, & Duarte, 2009; Castro & Mesquita, 2010). *Setting conditions* concerned the place where the setter executed the setting action and was assessed by the number of attack options available: excellent conditions (EC), the setter had all attack options fully available (i.e. all players were available to participate in attack organisation, in all attack zones, at all attack tempos, with the possibility of using simple and complex attack combinations); reasonable conditions (RC), the setter had fewer attack options that still afforded rapid attacks involving a middle-attacker (i.e. attack tempos 1, 2 and 3, but not tempo 0), which limited the type of attack combinations (i.e. they were only simple attack combinations); weak conditions (WC) that only afforded setting high balls to the wings of the court with the slowest attack tempos (i.e. tempos 2 and 3), which is more predictable for the opposition defence. *The attack zone* corresponded to the zone where the hitter contacted the ball. These corresponded to the six formal zones of the volleyball game established by the FIVB. Four different attacking tempos were considered: tempo 0 (very fast, the attacker jumped before the set), tempo 1 (fast, the attacker jumped immediately after the set), tempo 2 (slow, the attacker took three-steps and jumped after the set) and tempo 3 (very slow, the attacker had time to wait after the set was made and then started a three-step approach to the jump position) (adapted from Afonso, Mesquita, Marcelino, & Silva, 2010). *The block opposition* corresponded to the number of blockers opposing the attack: no-block (0), single-person block (1), double-person block (2) and triple-person block (3). Concerning *set type*, the first two sets of each game were considered non-decisional sets (NDS) and the set that enabled a team to win the match as a DS. Regarding the *set period*, we considered two periods of the set: initial set period (ISP) that corresponded to the game period until the first technical time-out, so 0 to 8 points; final set period (FSP) that comprised the period after the second technical time-out and the end game, so usually between 17 and 25 points.

Variability in values of four dependent variables (setting conditions, attack zone, attack tempo and block opposition) was assessed by measuring the *entropy* of the eight teams at each level. Shannon entropy measures have been used as an important tool to evaluate the uncertainty of an informational variable (Shannon, 1948) and to quantify its complexity (Yentes et al., 2013). Considering a volleyball game action (e.g. attack tempo) with N possible variants (e.g. tempo 0, 1, 2 and 3), and setting pi as the measured probability of occurrence for this specific action in one game set through the form of variant i (e.g. tempo 1), the entropy S of this game action for this set is:

$$S = -\sum_{i=1}^{N} pi \log pi.$$

The higher the entropy (i.e. the closer to log N, which is the maximum entropy value for a given game action with a uniform distribution), the more uncertainty (or variability) is associated with an analysed variable (see Silva, Duarte, Esteves, Travassos, & Vilar, 2016). Entropy values near zero signify that a variable can be easily predicted. Thus, the entropy value of selected variables was interpreted as specifying higher or lower levels of spatial variability (or uncertainty) between the attacking zones and setting conditions and higher or lower levels of action variability (or uncertainty) in attack tempo and block opposition organisation.

Procedures

The analysed matches from the Olympic Games competition were obtained through DVD in high-definition (1080p) format. The Portuguese national league matches were video recorded under the same competitive conditions, with a static video camera positioned laterally to provide a side view of the court.

Reliability

Data reliability was measured through intra- and inter-observer testing procedures. The first researcher reviewed three games after a one-month period in order to prevent any learning effects. A second observer analysed three other different games within the same period. Intra-observer reliability presented Kappa values ranging from 0.814 to 1.000, while inter-observer reliability ranged from 0.900 to 1.000, in all cases fulfilling the minimum of 0.75 suggested previously (Fleiss, 2003).

Statistical analysis

Data on attack zone, setting conditions, attack tempo and block opposition were analysed for practical significance differences using magnitude-based inferences via pooled standard deviations. Effect sizes (standardised mean difference – SMD) with 90% confidence intervals were calculated between elite and NL samples (i.e. elite–national) (Hopkins, Marshall, Batterham, & Hanin, 2009). Threshold values for the effect sizes were > 0.2 (small), > 0.6 (moderate) and > 1.2 (large) (Cohen, 1988). Probabilities were estimated to assess whether true effects obtained represented substantial changes in performance behaviours (Batterham & Hopkins, 2006). In this study, the smallest standardised change in each variable was considered to be 0.2 multiplied by the between-individual standard deviation value, based on Cohen's effect size principle (Buchheit & Mendez-Villanueva, 2014). Quantitative probabilities of higher or lower differences were evaluated qualitatively as: < 1%, almost certainly not; 1–5% very unlikely; 5–25%, unlikely; 25–75%, possible; 75–95%, likely; 95–99%, very likely; > 99%, almost certain (Hopkins, 2002). If the probability of the effect being higher or lower than the smallest worthwhile difference was simultaneously > 5%, the observed effect was deemed unclear. Otherwise, the effect was proposed as clear and reported as the magnitude of the observed value.

Results

We analysed 850 EL action sequences (588 in IS and 262 in the DS) and 646 NL action sequences (423 in IS and 223 in the DS). From the video recordings, we analysed 1011 rallies in NDS and 485 in DS. At the initial period of the set, data were collected from 465 rallies (255 for EL and 210 for NL), and at the final period of the set we analysed data from 483 rallies (284 for EL and 199 for NL). Table I shows a descriptive analysis of setter position, attack zone, attack tempo and block opposition considering expertise levels, set type and set period.

Figure 1(a) illustrates the standardised mean differences between the two groups (i.e. EL–NL) for entropy values of all variables. Results indicated that, in attack zones, group differences were likely moderate, with the EL players displaying more spatial variability in attack (with changes of greater / similar / lower values of 91/0/9). Compared to participants in the EL group, the NL players revealed an almost certainly large effect (1/0/99), with more irregular actions in setting conditions and block opposition. Analysis of attack tempo revealed a likely small (82/0/18) effect, with the EL group displaying higher levels of unpredictability in type of attack used.

Figure 1(b) depicts the standardised mean differences between entropy values in the two groups (i.e. EL–NL), for all variables in different types of set. In the NDS, for setting conditions and attack tempo, differences in entropy values were very likely moderate (5/0/95 and 95/0/5, respectively). The EL players displayed less variability than NL players in setting conditions, with the inverse emerging in attack tempo. Also, construction of block opposition revealed a likely moderate effect size (2/0/98), with the NL participants displaying greater variability. The attack zone values demonstrated a likely small effect (85/1/4), with EL teams revealing greater unpredictability. In DS, between-group differences were possibly trivial (53/2/45) in the attack zone. Compared to the EL teams, the actions of the NL teams were almost certainly large (0/0/100) and more irregular in the setting conditions. Attack tempo and block opposition analyses revealed likely small (13/1/86) and very likely moderate (2/0/98) effect sizes, respectively. In both analyses, the NL teams displayed greater irregularity in performance behaviours.

Figure 1(c) demonstrates the standardised mean differences of each group (i.e. EL–NL) in all variables concerning the entropy values in distinct set periods. Regarding initial set periods, setting conditions and block opposition present almost certain and very likely large differences (1/0/99 and 97/2/1, respectively), with NL teams displaying more variability than EL teams for both variables. On the other hand, attack tempo showed a likely moderate effect size (88/1/11) with EL reflecting more uncertainty. A possible trivial difference (97/2/1) could be observed in attack zone. Towards the final set periods, attack zone and setting conditions denoted a very likely moderate effect size (95/1/4 and 2/0/98, respectively), with EL players revealing more variability in the attack zone and less variability in the setting zone compared to NL players. Moreover, we observed a likely small effect size for attack tempo and block opposition (81/2/17 and 65/3/32, respectively). In both cases, the EL teams presented greater unpredictability than NL teams.

Table I. Descriptive analysis of all variables, considering the groups, type and set periods

Variables	Non-decisional sets					Decisional sets					Initial set periods					Final set periods				
Groups	Counts (%) EL	NL	SMD	LCL	UCL	Counts (%) EL	NL	SMD	LCL	UCL	Counts (%) EL	NL	SMD	LCL	UCL	Counts (%) EL	NL	SMD	LCL	UCL
Setting Conditions			−0.84	−1.66	−0.02			−1.54	−2.36	−0.71			−1.34	−2.16	−0.52			−1.08	−1.90	−0.26
1 *– Excellent Conditions*	79	64	*Moderate*			79 =	62↓	*Large*			78	63	*Large*			80↑	64↑	*Moderate*		
2 *– Reasonable Conditions*	17	28				16↓	30↑				19	30				16↓	25↓			
3 *– Weak Conditions*	4	8				5 ↑	8 =				3	7				4 ↑	11↑			
Attack zone			0.50	−0.31	1.33			0.05	−0.78	0.87			−0.11	−0.93	0.71			0.85	0.03	1.68
1 *– Zone 1*	3	2	*Small*			3 =	3↑	*Trivial*			1	1	*Trivial*			6 ↑	2 ↑	*Moderate*		
2 *– Zone 2*	26	25				23↓	30↑				25	26				23↓	24↓			
3 *– Zone 3*	18	22				20↑	17↓				20	21				20 =	20↓			
4 *– Zone 4*	45	45				46↑	46↑				46	45				43↓	52↑			
6 *– Zone 6*	8	6				8 =	4↓				8	7				8 =	2 ↓			
Attack tempo			0.84	0.01	1.66			−0.54	−1.36	0.28			0.60	−0.22	1.42			0.45	−0.38	1.27
0 *– Very fast*	18	16	*Moderate*			17↓	15↓	*Small*			18	15	*Moderate*			16↓	17↑	*Small*		
1 *– Fast*	34	30				36↑	34↑				34	31				37↑	27↓			
2 *– Slow*	34	37				33↓	32↓				34	38				34 =	35↓			
3 *– Very slow*	14	17				14 =	14↓				14	16				13↓	21↑			
Block Opposition			−1.06	−1.88	−0.23			−1.05	−1.87	−0.23			−1.05	−1.87	−0.22			0.21	−0.61	1.03
0 *– No-block*	1	5	*Moderate*			0 ↓	5 =	*Moderate*			0	4	*Large*			1 ↑	4 =	*Small*		
1 *– Single block*	22	23				25↑	26↑				24	28				22↓	24↓			
2 *– Double block*	75	71				74↓	68↓				75	67				74↓	72↑			
3 *– Triple block*	2	1				0 ↓	0 ↓				1	1				3 ↑	0 ↓			

Note*:* SMD = Standardised Mean Difference (elite–national level); LCL = lower confidence limits; UCL = upper confidence limits; ↑ = increase; ↓ = decrease; = equal. The numbers in bold represent the values used to codify each variable (i.e. the variants that each variable could assume).

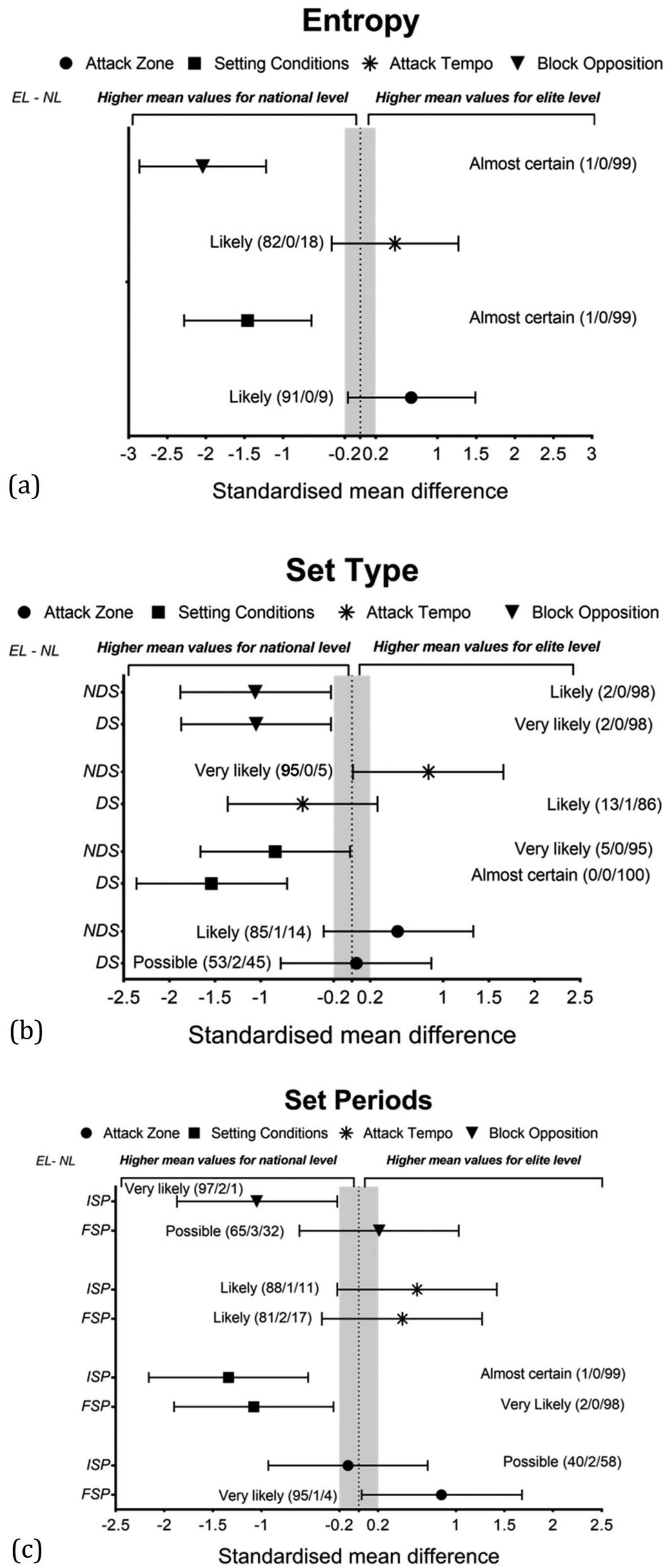

Figure 1. Standardised mean differences between the two groups (elite–national level) for entropy values of all variables (a), according to type of set (b) and set periods (c). *Error bars* indicate the uncertainty in the true mean changes with 90% confidence limits.

Discussion

This study sought to compare the variability of complex I tactical performance indicators in female volleyball teams at two distinct competitive levels (elite and national). We also sought to examine whether variability of performance indicators was influenced by contextual constraints like set type (i.e. NDS and DS) and set period (i.e. initial set periods and final set periods). Overall, results revealed differences between EL and NL teams in all key performance variables (i.e. setting conditions, attack zone, attack tempo and block opposition), which were more marked when set type and set periods were also taken into account.

The novelty of our study is based on analysis of entropy values, which provided important information on the uncertainty and variability of tactical behaviours that emerged under different competitive constraints (Vilar et al., 2013). Measures of variability are important since they provide a window into how expertise shapes performance in team sports, highlighting central features of skilled and less skilled behaviours (see Silva, Duarte, et al. (2014), for example, in association football). As expected, results showed that EL teams displayed higher levels of variability in attack actions making it difficult for opposition blocks to anticipate outcomes. They also showed greater variability in zones and tempos of attack. On the other hand, EL teams were less variable in excellent setting conditions (i.e. high frequency of all hitters available) and in block opposition (i.e. double block being the most frequent). Such findings suggest that a high stability (i.e. lower variability) in setting conditions can elicit greater manipulation of space and tempo in organising attacks, which, in turn, limits opposition defensive organisation. Therefore, we can safely speculate that the greater variability demonstrated by NL teams in such behaviours (i.e. setting conditions and block opposition) was mainly non-functional variability.

Notwithstanding, excellent setting conditions were the most frequently observed at both expertise levels suggesting that one of the biggest differences between EL and NL teams is the higher skills of EL setters and a more refined level of team collective organisation. In other words, the performance behaviours of elite setters were predicated on coherent, collective decision-making. These findings strongly support the key ideas of a dynamical systems orientation for understanding team sport performance since it highlights the continuous and dynamic interactions between a range of performance variables, which emerge under the ecological constraints of competitive performance (Davids et al., 2015; McGarry, Anderson, Wallace, Hughes, & Franks, 2002).

In decisional sets (i.e. sets that determine match outcomes) EL teams presented less variability in excellent setting conditions. In attack zones, both groups decreased attack variability (i.e. tempo and zone of attack) with a more marked tendency emerging in the EL group. This could be explained by the predominance of attacks performed by EL players in zone 3 and also the use of a faster attack tempo. Zone 3 is the frontal central zone of the court where a setter can regulate offensive organisation, spatially and temporally manipulating attacks (Castro & Mesquita, 2010). Therefore, attacking through zone 3 might have increased a team's scoring opportunities since it limits opposition defensive organisation (Castro et al., 2011). Final set periods can be considered critical moments that differentiate team expertise levels. Within this period, EL teams showed less variability in creating excellent setting conditions in the attack zone compared to NL teams. The EL teams opted to temporally vary their attacks, but not the zones. These data suggest that EL setters sought the best hitter for an attack or opted for their best set (playing conservatively inside their 'comfort zone') in critical situations. They decreased variability and became a little more stable, but also allowed a key variable to vary: using more rapid attacks. This interpretation of our observations supports data previously reported by Mesquita and Graça (2002) who suggested that a setter's decision-making involves the integration of a variety of information that generates different strategic options. This finding is also in agreement with the results of a study by Marcelino, Sampaio, and Mesquita (2012) who demonstrated that volleyball matches present different tactical profiles depending on the game period.

In future research, it is recommended that other volleyball game complexes (i.e. complex II or counter-attack) and other competitive levels (i.e. Grand Prix, World League, other national levels) are analysed, as well as extending the present methodology to the study of male and youth volleyball competitions, implementing a longitudinal design.

Conclusion

A dynamical systems interpretation of tactical performance behaviours in volleyball teams was supported by our performance analysis. Unpredictability in attacking actions was shown to be a key factor that could only be achieved with greater performance stability, afforded by lower levels of variability in some game actions (e.g. creation of excellent setting conditions). Findings of this study also highlighted how variability in sports teams, considered as complex adaptive systems, is expressed differently in tactical behaviours at different expertise levels. Data revealed how EL teams displayed better resources to exploit adaptive and functional system variability during critical moments of a competition (i.e. in a DS and during the final set periods).

Results reported here may guide coaches to exploit processes of co-adaptation in teams as complex adaptive systems by manipulating competitive constraints during training sessions. For instance, this could be achieved by manipulating scenarios based on match scores during practice to increase pressure on a setter, affording them valuable experience to prepare teams and tactical plans, according to predicted opposition behaviours during a match. In line with this, it is important that coaches work strategically with NL setters in order to improve their tactical behaviours at critical moments in competition. Last, it is suggested that coaches should develop co-adaptive behaviours in setters by helping them acquire the capacity to play at more rapid tempos and to diversify zones of attack.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Afonso, J., & Mesquita, I. (2011). Determinants of block cohesiveness and attack efficacy in high-level women's volleyball. *European Journal of Sport Science*, *11*(1), 69–75. doi:10.1080/17461391.2010.487114

Afonso, J., Mesquita, I., Marcelino, R., & Silva, J. A. (2010). Analysis of the setter's tactical action in high-performance women's volleyball. *Kinesiology*, *42*(1), 82–89.

Afonso, J., Moraes, J., Mesquita, I., Marcelino, R., & Duarte, T. (2009). Relationship between reception effect, attack type and attack tempo with performance level in high-level men's volleyball. *Journal of Sports Sciences*, *27*(4), S128.

Araújo, D., Davids, K., Bennett, S., Button, C., & Chapman, G. (2004). Skill acquisition in sport: Research, theory and practice. In A. M. Williams & N. J. Hodges (Eds.), *Emergence of sport skills under constraints* (pp. 409–434). London: Taylor & Francis.

Araújo, D., Silva, P., & Davids, K. (2015). Capturing group tactical behaviours in expert teams players. In J. Baker & D. Farrow (Eds.), *Routledge Handbook of Sport Expertise* (pp. 209–220). New York, NY: Routledge.

Batterham, A., & Hopkins, W. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance*, *1*(1), 50–57. doi:10.1123/ijspp.1.1.50

Buchheit, M., & Mendez-Villanueva, A. (2014). Effects of age, maturity and body dimensions on match running performance in highly trained under-15 soccer players. *Journal of Sports Sciences*, *32*(13), 1271–1278. doi:10.1080/02640414.2014.884721

Castro, J., & Mesquita, I. (2010). Analysis of the attack tempo determinants in volleyball's complex II – a study on elite Male teams. *International Journal of Performance Analysis in Sport*, *10* (3), 197–206.

Castro, J., Souza, A., & Mesquita, I. (2011). Attack efficacy in volleyball: Elite Male teams. *Perceptual and Motor Skills*, *113*(2), 395–408. doi:10.2466/05.25.PMS.113.5.395-408

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: L. E. Associates Ed.

Davids, K., & Araújo, D. (2005). The constraints-led approach in sport training. In D. Araújo (Ed.), *The context of decision. The tactical action in sport.* (pp. 35–60). Lisbon: Visão e Contextos.

Davids, K., Araújo, D., Seifert, L., & Orth, D. (2015). Expert performance in sport: An ecological dynamics perspective. In J. Baker & D. Farrow (Eds.), *Routledge handbook of sport expertise* (pp. 273–303). London: Routledge.

Davids, K., Savelsbergh, G., & Bennett, S. (2002). *Interceptive actions in sport: Information and movement*. London: Routledge.

Duarte, R., Araújo, D., Folgado, H., Esteves, P., Marques, P., & Davids, K. (2012). Capturing complex, non-linear team behaviours during competitive football performance. *Journal of Systems Science and Complexity*, *26*, 62–72. doi:10.1007/s11424-013-2290-3

Fleiss, J. L. (2003). *Statistical methods for rates and proportions* (3rd ed.). New Jersey: Wiley-Interscience.

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

Hopkins, W. (2002). Probabilities of clinical or practical significance. *Sportscience*, *6*. Retrieved from sportsci.org/jour/0201/Statistical_vs_clinical.ppt website

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, *41*, 3–13. doi:10.1249/MSS.0b013e31818cb278

Hristovski, R., Davids, K., & Araújo, D. (2006). The ecological dynamics of decision making in sport. *Psychology of Sport and Exercise*, *7*(6), 653–676. doi:10.1016/j.psychsport.2006.07.002

Jorg, J., & Wolfgang, S. (2007). Situation-orientated recognition of tactical patterns in volleyball. *Journal of Sports Sciences*, *25*(12), 1345–1353. doi:10.1080/02640410701287230

Males, J., Kerr, J., Thatcher, J., & Bellew, E. (2006). Team process and players' psychological responses to failure in national volleyball team. *Sport Psychologist*, *20*, 275–294. doi:10.1123/tsp.20.3.275

Marcelino, R., Mesquita, I., & Sampaio, J. (2010). Efficacy of the volleyball game actions related to the quality of opposition. *The Open Sports Sciences Journal*, *3*, 34–35. doi:10.2174/1875399X01003010034

Marcelino, R., Sampaio, J., & Mesquita, I. (2012). Attack and serve performances according to the match period and quality of opposition in elite volleyball matches. *Journal of Strength and Conditioning Research*, *26*(12), 3385–3391. doi:10.1519/JSC.0b013e3182474269

Martín, J. J. M., & Santandreu, C. S. (2009). The strategic complexes. In J. J. M. Martín & C. S. Santandreu (Eds.), *Tactical volleyball* (pp. 33–42). Badalona: Editorial Paidotribo.

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

Mesquita, I., & Graça, A. (2002). Probing the strategic knowledge of an elite volleyball setter: A case study. *International Journal of Volleyball Research*, *5*(1), 13–16.

Mesquita, I., Paolo, J., Marcelino, R., & Afonso, J. (2012). Perform analysis in indoor volleyball and beach volleyball. In T. McGarry, P. O'Donoghue, & J. Sampaio (Eds.), *Routledge handbook of sports performance analysis* (pp. 367–379). London: Routledge.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). London: Sage.

Rhea, C. K., Silver, T. A., Hong, S. L., Ryu, J. H., Studenka, B. E., Hughes, C. M. L., & Haddad, J. M. (2011). Noise and complexity in human postural control: Interpreting the different estimations of entropy. *PLoS ONE*, *6*(3), 1–9. doi:10.1371/journal.pone.0017696

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

Shannon, C. (1948). A mathematical theory of communication. *The Bell System Technical Journal*, *27*(3), 379–423. doi:10.1002/j.1538-7305.1948.tb01338.x

Sheppard, J., Gabbett, T., & Stanganelli, L.-C. (2009). An analysis of playing positions in elite men's volleyball: Considerations for competition demands and physiologic qualities. *Journal of Strength and Conditioning Research*, *23*(6), 1858–1866. doi:10.1519/JSC.0b013e3181b45c6a

Silva, P., Aguiar, P., Duarte, R., Davids, K., Araújo, D., & Garganta, J. (2014). Effects of pitch size and skill level on tactical behaviours of association football players during small-sided and conditioned games. *International Journal of Sport Science & Coaching*, *9*(5), 992–1006. doi:10.1260/1747-9541.9.5.993

Silva, P., Duarte, R., Esteves, P., Travassos, B., & Vilar, L. (2016). Application of entropy measures to analysis of performance in team sports. *International Journal of Performance Analysis in Sport*, *16*, 753–768.

Silva, P., Duarte, R., Sampaio, J., Aguiar, P., Davids, K., Araujo, D., & Garganta, J. (2014). Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football. *Journal of Sports Sciences*, *32*(20), 1888–1896. doi:10.1080/02640414.2014.961950

Silva, P., Esteves, P., Correia, V., Davids, K., Araujo, D., & Garganta, J. (2015). Effects of manipulations of player numbers vs. Field dimensions on inter-individual coordination during small-sided games in youth football. *International Journal of Performance Analysis in Sport*, *15*, 641–659.

Stergiou, N., & Decker, L. M. (2011). Human movement variability, nonlinear dynamics, and pathology: Is there a connection? *Human Movement Science*, *30*, 869–888. doi:10.1016/j.humov.2011.06.002

Stergiou, N., Harbourne, R. T., & Cavanaugh, J. T. (2006). Optimal movement variability: A new theoretical perspective for neurologic physical therapy. *Journal of Neurologic Physical Therapy*, *30*(3), 120–129. doi:10.1097/01.NPT.0000281949.48193.d9

Vilar, L., Araújo, D., Davids, K., & Bar-Yam, Y. (2013). Science of winning soccer: Emergent pattern-forming dynamics in association football. *Journal of Systems Science and Complexity*, *26*(1), 73–84. doi:10.1007/s11424-013-2286-z

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