# Entropy measures reveal collective tactical behaviours in volleyball teams: how variability and regularity in game actions influence competitive rankings and match status

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# Entropy measures reveal collective tactical behaviours in volleyball teams: How variability and regularity in game actions influence competitive rankings and match status

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**Abstract**

This study analysed and compared the influence of match status and final team rankings on variability of tactical performance behaviours within complex I, in female volleyball teams of different competitive levels. Performance data were analysed from matches (n=8 in each level) in the 2012 Olympic women's volleyball competition (elite level) and the Portuguese women's league (national level) in the 2014-2015 season, with a total of 1496 rallies observed. Variability of setting conditions, attack zone, attack tempo and block opposition was assessed using Shannon entropy measures. Magnitude-based inferences were used to analyse and compare values of selected variables. Results showed that current match status had no influence on tactical performance of elite teams showing that they adapted their collective organization without losing their game patterns. Analysis of final team rankings showed that, at national level, the highest ranked teams revealed greater unpredictability in all tactical performance measures (mainly in attack tempo and block opposition), emphasizing the importance of the setter to differentiate performance of national teams. These findings may guide coaches in designing practice contexts for developing specific game patterns (setting conditions) and in seeking greater variability in other game actions (in attack), regardless of competitive level of performance.

**Keywords:** performance analysis, entropy, match status, final team rankings, volleyball

## 1. Introduction

From an ecological dynamics perspectives, team sports have been viewed as dynamical and complex systems, endowed with 'degeneracy', signifying that the same competitive performance outcomes can be achieved in different ways (Duarte, et al., 2013; Seifert, Komar, Araújo, & Davids, 2016a). This inherent property of complex adaptive systems provides sports teams with the capacity of explore different technical and tactical solutions during competition (Ramos, Coutinho, Silva, Davids, & Mesquita, 2017; Seifert, et al., 2016a; Travassos, Araújo, Duarte, & McGarry, 2012). Since competitive environments are changing constantly, the system property of degeneracy enables teams to adapt and self-organize in response to changing performance constraints systematically (Rein, Davids, & Button, 2009). To achieve this functional adaptation, a balance between variability and stability of game actions is needed (Seifert, Komar, Araújo, & Davids, 2016b). Therefore, increases and decreases in performance variability may result in the loss of a team’s adaptability (Araújo & Davids, 2016; Frencken, Poel, Visscher, & Lemmink, 2012).

In volleyball, the importance of promoting adaptive variability in some game actions (i.e., attack actions) has been recognised by coaches to avoid predictability, highlighting the need to help performers exploit different performance solutions when competitive conditions change (Ramos, et al., 2017; Silva, et al., 2015; Travassos, Araújo, Vilar, & McGarry, 2011). However, as the first contact is usually directed for one specific zone on court, only in the second contact can the setter (player that executes the setting action) introduce variability in an attack action (for instance, by manipulating tempo and zone of attack). This is mostly noted in complex I (the side-out, game-phase that comprises the actions of service-reception, setting and attacking) (Martín & Santandreu, 2009; Mesquita, Paolo, Marcelino, & Afonso, 2012). In this complex, the setter has more time to prepare a pattern of attack where performance variability can be increased.

Research on performance analysis in sport has recently examined the variability of game actions and game-phases using non-linear measures (e.g., Shannon entropy) in order to understand how teams vary their tactical behaviours under different performance constraints (Duarte, et al., 2013b; Silva, et al., 2014a; Vilar, Araújo, Travassos, & Davids, 2014; Vilar, Santos, Araújo, & Davids, 2011). Indeed, the use of Shannon entropy measures has revealed how the need to satisfy different performance constraints might lead to the emergence of specific patterns of behaviours. For instance, a study by Vilar, Araújo, Davids, and Bar-Yam (2013) applied Shannon entropy measures to analyse the local numerical relations between competing players during a competitive professional football match, showing that the greatest uncertainty in numerical relations emerged in the central midfield area of play. Additionally, Ramos, et al. (2017) used Shannon entropy measures to assess the variability of volleyball game actions, highlighting that variability of tactical behaviours was expressed differently between distinct competitive levels, as well as within critical game phases (during a decisional set and final set period). However, the findings of this previous study highlighted other important issues to investigate further. For instance, the data raised questions about the required differences in tactical behaviours to adapt to key, emergent contextual constraints (e.g., match status and final teams ranking). Analyses of these variables are scarce in literature, and undertaking this investigation could reveal a deeper understanding of the tactical behaviours of sports teams at different levels of competition.

Indeed, match status (i.e., the game score when specific tactical indicators were recorded) is considered a core situational variable that can influence the emergence players' tactical behaviours during competition (Lago, 2009; Marcelino, Mesquita, & Sampaio, 2011). Various studies in team sports, such as football (Almeida, Ferreira, & Volossovitch, 2014; Baranda & Lopez-Riquelme, 2012; Taylor, Mellalieu, James, & Shearer, 2008), handball (Prieto, Gómez, Volossovitch, & Sampaio, 2016) and basketball (Gomez, Jimenez, Navarro, Lago-Penas, & Sampaio, 2011) have shown that match status is a contextual constraint that shapes the emergent strategic behaviours of teams. Considering team sports as complex adaptive systems (Araújo & Davids, 2016), several studies have analysed the influence of match status on a team's emergent technical and tactical performance (Almeida, et al., 2014; Baranda & Lopez-Riquelme, 2012; Lago, 2009; Palao, Manzanares, & Valadés, 2015). For instance, the study of Gomez, et al. (2011) highlighted the importance of coaches analysing offensive and defensive performances according to game period and score differences when considering whether to call a timeout. Specifically in volleyball, a study by Marcelino, et al. (2011) concluded that male teams take more risks in asymmetric score situations (i.e., when teams are clearly winning or losing).

Research in volleyball has also studied the association between a final team rankings (i.e., final standings in a given competition) and their performance outcomes (i.e., quantitative analysis of game actions) (Drikos, Kountouris, Laios, & Laios, 2009; Medeiros, Oliveira, Afonso, Loureiro, & Mesquita, 2011; Stutzig, Zimmermann, Büsch, & Siebert, 2015). For instance, Marcelino, Mesquita, and Sampaio (2008) verified that, at an elite level, the most successful teams fault on a higher number of serves, but also win more points with the service action. Notwithstanding, little is known in volleyball research about the level of variability which emerges in teams' tactical behaviours as a function of their final rankings at different competitive levels of performance (e.g. international teams compared to national level teams).

Thus, the aims of the present study were twofold. First, we sought to examine the performance variability of volleyball teams at different competitive levels (i.e., elite and national level) in complex I according to ongoing changes in match status (i.e., in winning and losing situations). Second, we sought to analyse whether variability of these key performance indicators could be related to each final team rankings at the different competitive levels.

## 2. Methods

### *2.1 Participants*

Convenience and purposive sampling criteria (Patton, 2002) were used to select the teams from the Portuguese national league. The Olympic competition was chosen because it includes the most elite international volleyball teams globally. Two competitive levels were considered: an Elite Level (EL), which comprises the top eight ranked teams in the Olympic Games 2012; and a National Level (NL), comprising the top eight ranked teams in the Portuguese 2014-2015 national league. For the EL group, all matches from the quarter-finals to the final of the Olympic competition were analysed, yielding a total of eight matches observed. For the NL group, we observed the last three games of the top four ranked teams in the league and the final game of the four teams ranked from fifth to eighth, with a total of eight matches examined.  Performance in a total of 60 sets (30 from each group) and 1496 rallies was observed. This study was approved by the local Institutional Research Ethics Committee and followed to the recommendations of the Declaration of Helsinki.

### *2.2 Variables*

The variables analysed in this study were: *setting conditions*, *attack zone*, *attack tempo*, and *block opposition.* These variables were selected since they conveniently characterize the complex I phase of play (Lobietti, Cabrini, & Brunetti, 2009; Paulo, Zaal, Fonseca, & Araújo, 2016). Additionally, these variables were analysed with respect to the current *match status* and the *final teams raking.*

The *setting conditions* corresponded to the place where the setter executed the setting action and was assessed by the number of attack options accessible: excellent conditions (EC), the setter had all attack options fully accessible (i.e. all players were available to participate in an attack, through all zones and tempos of attack and yet with the possibility of using simple and complex offensive combinations); reasonable conditions (RC), the setter had fewer attack options but still afforded quick attacks involving a middle-attacker (i.e. attack tempos 1, 2 and 3, but not tempo 0) and simple offensive combinations; weak conditions (WC) that only afforded setting with slowest tempos of attack (i.e. tempos 2 and 3) to the wings of the court, which is more predictable for opponents to defend against. The *attack zone* corresponds to the zone where the hitter contacts the ball during the attack action. In this analysis, we considered the six formal zones of the volleyball game established by the FIVB. The *attack tempo* is defined as the temporal relation between the approach of the attackers and the moment the ball leaves the setter's hands (Afonso & Mesquita, 2007b). According to Ramos, et al. (2017) four attack 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); tempo 3 (very slow, the attacker had time to wait after the set and then started a three-step approach to the jump position). The *block opposition* corresponds to the number of opponent blockers involved in defending against an attack: no-block (0), single block (1), double block (2) and triple block (3). The *match status* was considered in terms of sets (i.e., winning or losing at least one set) and two possible scenarios were considered: winning (WIN) and losing (LOS) situations. The *final team rankings* corresponds to the final competitive standings of each team, and two sub-levels were created within each competitive level: elite level 1 (EL1) and national level 1 (NL1), that corresponds to the first four ranked teams; elite level 2 (EL2) national level 2 (NL2) that comprises the last four ranked teams. Both sub-levels comprise four teams to provide equal samples.

The variability in the values of the four dependent variables (setting conditions, attack zone, attack tempo and block opposition) was assessed using Shannon entropy measures. This measure assesses the uncertainty of an informational variable (Shannon, 1948) and quantifies their level of complexity (Silva, Duarte, Esteves, Travassos, & Vilar, 2016). For instance, considering the attack zone with *N* possible variants (e.g. zone, 1, 2, 3, 4, 5 and 6), 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., zone 1), the entropy S of this game action for this set is:

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

The higher the entropy value (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 that variable (Silva, et al., 2016). On the other hand, when entropy values approximate zero, it signifies that a variable contains more predictability (i.e., low variability). 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.

*2.3 Procedures*

Matches from the 2012 Olympic Games competition were obtained and examined through DVD in a high definition format (1080p). The Portuguese national league matches (2014-15) were video recorded with a static video camera positioned laterally to provide a side view of the court. Reliability of the data were measured through intra- and inter-observer testing procedures. Three different games were reviewed by each researcher after a one-month period to avoid any learning effects. Intra-observer reliability revealed Kappa values ranging from 0.814 to 1.000. Inter-observer reliability levels ranged from 0.900 to 1.000, values which, in all cases, satisfied the minimum of level of 0.75 recommended (Fleiss, 2003).

*2.4 Data Analysis*

Existence of significance differences in setting conditions, attack zone, attack tempo and block opposition were investigated using magnitude-based inferences via pooled standard deviations. Effect sizes (standardised mean difference – SMD) with 90% confidence intervals were calculated between EL and NL participants (i.e., elite–national, EL1–EL2 and NL1–NL2) (Hopkins, Marshall, Batterham, & Hanin, 2009). Threshold values adopted for analysis of effect sizes were > 0.2 (small), > 0.6 (moderate) and > 1.2 (large) (Cohen, 1988). Probabilities were assessed to estimate whether true effects found 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 considered unclear. Otherwise, the effect was proposed as clear and reported as the magnitude of the observed value.

## 3. Results

This study analysed 491 EL rallies (232 in WIN and 259 in LOS) and 401 NL rallies (193 in WIN and 208 in LOS). In total, we observed 425 sequences in WIN and 467 sequences in LOS. Regarding final team rankings, we examined 850 rallies (439 from EL1 and 411 from EL2) for elite level and 646 rallies (492 from NL1 and 154 from NL2) for national level participants. A descriptive analysis of setting conditions, attack zone, attack tempo and block opposition taking into account the match status and final team rankings is presented in table 1.

Figure 1 (a) represents the standardised mean difference between EL and NL in winning situations. Concerning setting conditions, results revealed that differences between both groups were moderate (with changes of greater/similar/lower values of 1/0/99), with EL teams showing more regularity in setting conditions than NL teams. Analysis of attack tempo revealed a possible small effect (66/3/31), with EL players displaying greater regularity in this variable. In terms of attack zones, EL teams demonstrated a likely trivial effect (92/1/7), characterised by greater spatial variability. Regarding block opposition, differences between groups were likely moderate (8/1/91), with NL players exhibiting higher variability in the number of block opponents used.

Figure 1 (b) illustrates the standardised mean differences between both groups (i.e., EL-NL) in losing situations. Results indicated that differences were very likely moderate (2/0/98) and likely small (20/2/78) for setting conditions and block opposition, respectively. For these variables, the NL teams expressed a greater variability than EL teams. Concerning attack tempo and zone, EL teams displayed a possible trivial (50/3/47) and a likely trivial (76/2/22) effect, respectively, showing greater unpredictability in these game actions.

Figure 1 (c) portrays the standardised mean differences between the first four (EL1 and NL1) and the last four (EL2 and NL2) ranked teams of each group. In the elite level group, EL1 (first four ranked) teams revealed a likely moderate effect (5/1/94) in setting conditions and attack tempo, which suggested greater predictability in these game actions, compared to EL2 (last four ranked) teams. At this competitive level, results still indicated a likely moderate effect for attack zone and block opposition (83/1/16 and 94/1/5, respectively), with EL1 displaying greater spatial unpredictability in the attack zone and a greater variability in the number of blockers used. In the national level group, the NL1 (first four ranked) teams revealed a possible small effect (72/2/26) in setting conditions, a likely moderate effect (88/1/11) in attack tempo, a possible trivial effect (58/3/39) in attack zone and a very likely large effect (98/0/2) in block opposition, compared to NL2 (last four ranked) teams. In short, the NL1 teams displayed greater spatial variability in setting conditions and block opposition as well as greater unpredictability in zones and tempos of attack.

*** please insert table 1 and figure 1 around here ***

## 4. Discussion

The present study sought to build on previous research by analysing effects of match status (winning and losing situations) and the final team rankings on variability of emergence of tactical performance indicators in female volleyball teams, within complex I. Overall, results showed that elite teams maintained their pattern of tactical behaviours, independent of match status. Additionally, analysis of final team rankings displayed clear differences within each competitive level in all key performance variables (i.e., setting conditions, attack zone and tempo and block opposition).

Contrary to our initial expectations, results showed that independent of being in winning and losing situations, when compared to national-level players, elite teams were less variable (i.e., more regular) in setting conditions, attack tempo and block opposition, and more variable (i.e., unpredictable) in selecting zones of attack. While elite level teams displayed greater frequency of excellent setting conditions (i.e., all hitters fully available) and used faster attack tempos, national level teams used slower attack tempos in WIN and faster attack tempos in LOS. Moreover, elite level teams increased the number of attacks in zone 3 (which is the frontal central zone of the court, featuring faster attacks tempos) in LOS, with the opposite occurring in national level teams. All these tactical behaviours showed how elite teams increased their scoring opportunities (Castro, Souza, & Mesquita, 2011). These findings are in line with data reported in a study by Ramos, et al. (2017) in female volleyball that revealed how high stability (i.e., lower variability) in setting conditions promoted a greater unpredictability in attack actions, limiting the defensive organization of opponents. It seems that match status has no influence on tactical performance in elite teams showing that they adapted their collective organization without losing their preferred tactical patterns. Such findings do not corroborate data reported by Marcelino, et al. (2011) in elite male volleyball teams. They concluded that teams modify their behaviours according to match status, taking more risks in games with asymmetric scores. The focus of the present study was on female teams and our findings are aligned with arguments of Costa, Afonso, Brant, and Mesquita (2012), who proposed how game patterns may substantially diverge according to gender of players, entailing technical and tactical implications for coaches. A possible explanation for this contrast in team tactical behaviours is the fact that female volleyball is predominantly played in complex II (the counter-attack, game-phase that comprises the actions of defence, setting and attacking). Thus, the results of the present study suggest that women teams are not so affected by contextual constraints in complex I.

The maintenance of tactical behaviours by elite players was not strongly influenced by contextual constraints. This finding appears to suggest the functional adaptation of elite teams in response to the greater competitive demands (Kinrade, Jackson, & Ashford, 2015). These ideas imply key principles for understanding performance in team sports from a dynamical systems viewpoint. The results reported here highlight the dynamical interactions that emerge between a range of performance variables under the ecological constraints of competitive performance (Davids, 2015; Davids, Araújo, Seifert, & Orth, 2015; McGarry, Anderson, Wallace, Hughes, & Franks, 2002). Here, using a non-linear measure (Shannon entropy), it was possible to assess the uncertainty and variability of tactical behaviours, allowing us to comprehend how teams systematically self-organized in response to the intrinsic constraints of competition. So, the assessment and analysis of performance variability allowed us to recognize the game patterns of teams at different performance levels (Ramos, et al., 2017; Silva, et al., 2016; Silva, et al., 2014). In this respect, the data shed insights into the role of different levels of expertise in the team sport of volleyball.

The current study is innovative in that it analyses whether variability could be related with final team rankings, at distinct competitive levels. Our analyses revealed some relevant differences, at each competitive level, which contradict results reported in a study by Stutzig, et al. (2015). They suggested that the impact of performance indicators in complex I are marginal in predicting the expertise level of male volleyball teams. At elite level, the highest ranked teams played regularly (i.e., with lower variability) creating excellent setting conditions, and using faster attack tempos, varying selected attack zones and the number of players used in their blocks. Our findings support the idea that teams with excellent setters, which can play with quick attack tempos, strongly increase the probabilities of scoring points in attacks (Bergeles, Barzouka, & Nikolaidou, 2009; Bergeles & Elissavet, 2011). Indeed, attack tempo is a decisive factor in destabilising the block opposition. This idea implies that the velocity of the attack plays a major role in destabilizing the oppositions defence, which in turn raises the odds of penetrating the defensive formation (Afonso, Mesquita, Marcelino, & Silva, 2010).

At national level, the highest ranked teams revealed greater unpredictability in all tactical performance indicators (mainly in attack tempo and block opposition). Such findings suggested that, even with increased variability in setting conditions (i.e., more reasonable and weak, conditions for setting), setters from the best national teams are capable of maintaining greater levels of unpredictability in attack organization (by manipulating the attack zone and tempo). Therefore, at national levels of competition, the greater variability observed in setting conditions and block opposition was less functional than that observed at elite levels of performance. What this means is that the performance unpredictability noted at national performance levels did not induce adaptive flexibility of team tactical behaviours) (Ramos, et al., 2017).

## 5. Conclusions

This study showed that elite teams were more consistent, and their performance was less dependent on match-status when they were leading or trailing in games. Results suggested that variability in attacking actions was a key factor in the success of the top four elite teams, which was predicated on greater performance stability in other game actions (i.e., setting conditions). Finally, results emphasized the importance of the setter in differentiating performance of national level teams.

Future studies should continue to examine team tactical behaviours using non-linear measures. Such analyses should be extended to analysis of other tactical performance indicators, such as attack efficacy, type and zone of service, setter's starting position, and effects of different phases of the competitive season. Moreover, future studies could focus on other game complexes (i.e., complex II and V) since they might reveal different performance features that could be influenced by competitive performance constraints. It is also recommended that researchers can use longitudinal designs, analysing different training approaches, in order to understand how different methods continuously shape team tactical behaviours and athlete performance over extended periods of time.

Results reported here highlight the importance for coaches of stabilizing specific game patterns (setting conditions) as well as creating greater variability in other game actions (attack), regardless of competitive level of performance. Additionally, it also seems relevant for coaches to manipulate match status during practice and to develop the setters' capacity for playing at faster tempos in diversified attack zones.

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