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The volleyball setter's decision-making on attacking[#]

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ABSTRACT

The aim of this study was to investigate the volleyball setter's decision-making on tipping, based on spatiotemporal variables of interaction between players and between players and the game environment. The sample consisted of 172 sequences of 20 volleyball games from 6 male and 10 female teams. The actions selected for analysis were 86 tips and 86 sets (control group), both made by the setters. From the players' *x* and *y* coordinates of displacement trajectory, 37 spatiotemporal measures of players' interaction were calculated as dependent variables, which were analysed by multivariate analysis of variance. Results showed that tips and sets differed in terms of (i) final area between opponents, (ii) displacement of setter to reach the ball, (iii) displacement velocity of setter to reach the ball, (iv) distance between setter and net in the initial moment, (v) distance between setter and net in the final moment, (vi) pass velocity and (vii) final distance between setter and blockers. It was concluded that these variables formed a spatiotemporal configuration of the game that influenced the setter's decision-making on tipping.

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1. Introduction

The ability to make decisions is a critical component of successful performances in fast ball sports such as volleyball. The dynamic of the volleyball game is characterised by the following regularity: a player receives the opposite service (e.g. first ball) and passes the ball to another player (setter), who touches it (e.g. second ball) to another attacker to perform a spike (e.g. third ball). Subsequently, the opposite team begins the defence with blockers (transition touch), and it continues (counterattack) by the receiver action, and so on. This dynamic is featured by frequent team ball possession exchanges, which includes skills with and without the ball. In such dynamic, the setter is considered the player responsible for making the most critical offensive decisions in volleyball as the one who organises the attack (Bezault, 2002; Palao, Santos, & Ureña, 2004, 2005).

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Notwithstanding the foregoing regularity in the dynamic of the game of volleyball, an interesting setter's decision-making is when he/she tips the ball instead of setting it to an attacker. This refers to an action of misleading the opponent, because the setter prepares to set but concludes with a kind of attack. In this action, one hand is removed when the ball is near both hands, and the ball is touched with a movement from top to bottom (Bezault, 2002; Lavega, 2002). The setter tip frequently occurs when this player plays in front positions.

Compared to other actions in volleyball, tips are less common (around 2–3%, according to Palao, Santos, & Ureña, 2007), exactly for being a setter's special action, which may result in a score. Because of its unpredictable nature, the tip can represent a perturbation factor in the defensive system (McGarry, Anderson, Wallace, Hughes, & Franks, 2002). A perturbation is an incident that changes the game's rhythmic flow, modifying the stable state of the system (Corrêa, Alegre, Freudenheim, Santos, & Tani, 2012; Hughes, Dawkins, David, & Mills, 1998). The tip can be conceived as a relatively rare phenomenon that has not been investigated, particularly concerning variables that may influence the decision to perform it. Then, the following question arises: On what information does the setter base the decision to attack by performing the tip?

Recently, ecological dynamics approach has emerged as a reliable framework for investigating players' decision-making in team sports, as it has been possible to comprehend such phenomenon at the ecological level of analysis, i.e. in the context in which it occurs (Araújo, Davids, & Hristovski, 2006; Vilar, Araújo, Davids, & Button, 2012). Accordingly, it has been proposed that players make decisions based on information about the action possibilities that emerge from their interactions (Araújo, Davids, Chow, Passos, & Raab, 2009; Passos, Araújo, Davids, Gouveia, Milho, et al., 2009b). In this research approach, such physical measures as angle (Corrêa, Vilar, Davids, & Renshaw, 2012; Passos, Araújo, Davids, Gouveia, Serpa, et al., 2009a), velocity and distance (Passos et al., 2008), time (Travassos, Araújo, Davids, et al., 2012), and area (Corrêa, Davids, Silva, Denardi, & Tani, 2014) have been used for assessing the interactions between players (interpersonal coordination) and between players and some aspects of the game environment (extrapersonal coordination) (Millar, Oldham, & Renshaw, 2013).

Interestingly, most studies in ecological dynamics have investigated players' decision-making in such invasive team sports such as basketball (Araújo, Davids, Bennett, Button, & Chapman, 2004; Cordovil et al., 2009), rugby (Correia et al., 2012; Passos, Cordovil, Fernandes, & Barreiros, 2012), futsal (Corrêa et al., 2016; Travassos, Araújo, Duarte, & McGarry, 2012) and soccer (Duarte et al., 2012; Romero, Denardi, Travassos, & Corrêa, 2016). An important point here is that the ways in which players interact in terms of opposing and cooperating in these team sports are different from those of net team sports such as volleyball.

While invasive team sports are characterised by a team occupying the other team's field to achieve its goal and by direct opposition, in net team sports, each team remains on its own side bounded by a net. Accordingly, there is no direct confrontation between attackers and defenders. In other words, there is a difference between the opposition and cooperation interaction modes in the sport of volleyball and those of invasive team sports. Therefore, the aim of this study was to investigate the volleyball setter's decision-making on tipping, based on spatiotemporal variables of interaction between players and between players and their game environment.

2. Methods

2.1. Sample

The sample consisted of 172 sequences from 20 volleyball games played during the 40th edition of the men and women's Paulista Championship 2013–Division I. This is one of the largest Brazilian professional championships of volleyball, held in the São Paulo state, from which about 6 male and 10 female teams, approximately 190 players participated. The actions selected for analysis were 86 tips and 86 sets (control group), both performed by the setters. For both categories of action, the sample was divided into 43 males and 43 females.

The sample selection process followed the emergence of the tip in the game and the set occurred immediately after. That is, all the setter tips were included and the next first set was selected for the control, independently of the team, or if it occurred in the same rally. Approximately 30 setters executed the selected actions. The local ethics committee of the University of Sao Paulo approved the research protocol.

2.2. Procedures

Concerning the data collection, the sequences of the game were selected from digital video footage of the aforementioned games. They were recorded by a digital camera (Casio HS EX-FH100) located above and behind the volleyball court. The images were captured in a frequency of 30 Hz and posteriorly adjusted to 25 Hz, using the Video Converter Factory software.

Specifically, the displacements of all the players were edited through TACTO software (Duarte et al., 2010; Fernandes, Folgado, Duarte, & Malta, 2010), from the moment the receiver touched the ball (initial moment “I”) to the moment the setter touched the ball (final moment “F”). The receiver was defined as the player who touches the ball before the setter. This procedure consisted of following the players' working point (projection of the centre of gravity of each individual player on the floor) in a slow-motion video image (frequency = 2 Hz), using a computer mouse.

This procedure allows the acquisition of the virtual x and y coordinates of each displacement trajectory (i.e. in pixels). After that, these coordinates were transformed into real coordinates by direct linear transformation (DLT2D) software and filtered with a low-pass filter (6 Hz) (Winter, 2005). This method considers the z coordinates to be equal to zero and directly correlates an object point located in the object space/plane with a corresponding image point on the image plane (Duarte et al., 2010; Fernandes et al., 2010).

The player's x and y coordinates of displacement trajectories and the calibration references were inserted into MATLAB software (2013a version), from which the following spatiotemporal variables of interaction (gaps) (Figure 1) were calculated:

- (a) *ABO gap* (Figure 1(a)): (i) *Area between opponents in the initial and final moments of the sequence [(ABO) I, (ABO) F]*. This was calculated by the equation:

$$A = |(x_1y_2 - y_1x_2) + (x_2y_3 - y_2x_3) \dots + (x_ny_1 - y_nx_1)/2|,$$

where x_1 refers to the coordinate x of player 1, y_n refers to the coordinate y of player n and so on. (ii) The *changing velocity of the area* [$v(ABO)$] was calculated through:

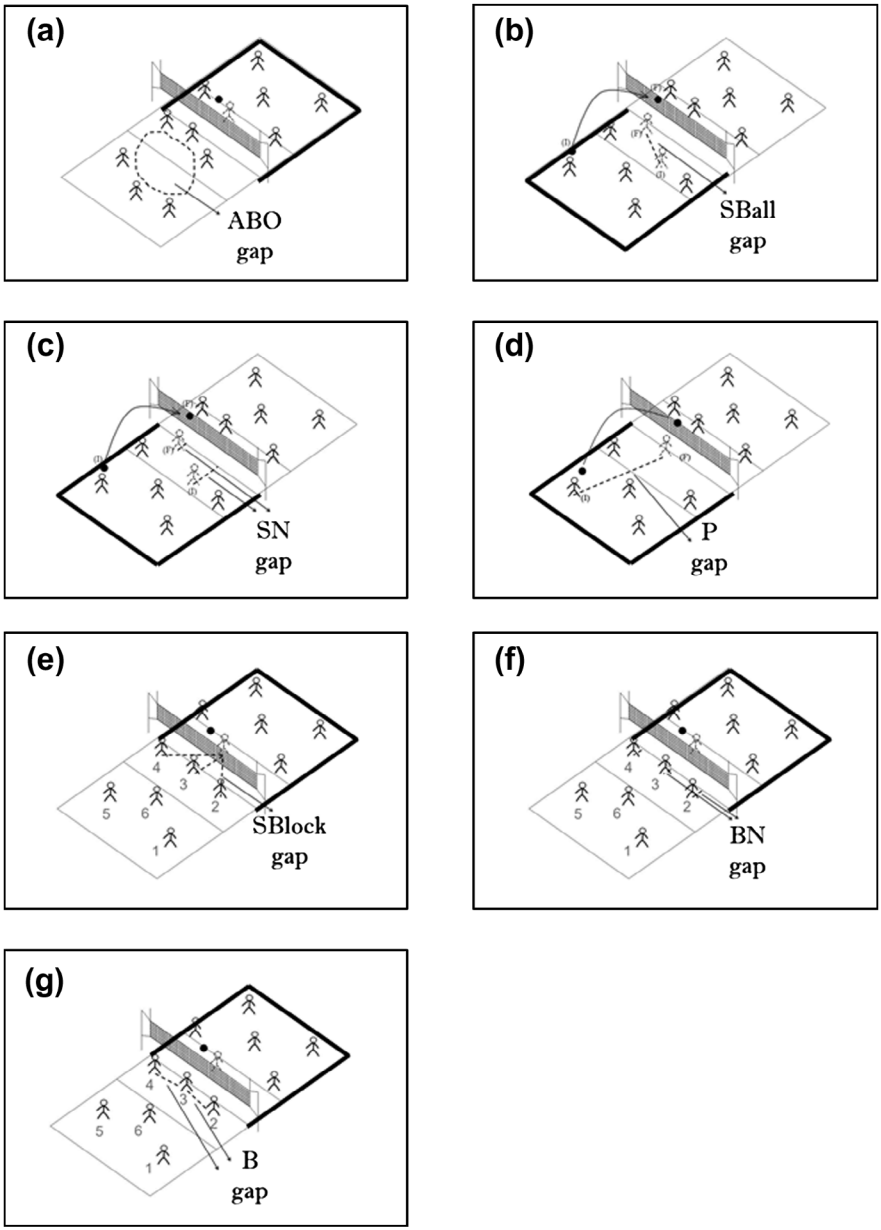


Figure 1. Illustration of the seven gaps: (a) *Area between opponents (ABO gap)* – dashed line represents the area, and dashed player represents the setter; (b) *Distance between setter and ball (SBall gap)* – dashed line represents the setter displacement from initial (I) to final moment (F), and the arrow represents the way of the ball; (c) *Distance between setter and net (SN gap)* – dashed lines represent the gaps between setter and net in the initial (I) and final moment (F) of the sequence; (d) *Pass distance (P gap)* – dashed line represents the distance between receiver and setter, from initial (I) to final moment (F), which characterises the ball displacement during the pass; (e) *Distance between setter and blockers (SBlock gap)* – dashed player represents the setter. Dashed lines represent gaps between setter and blockers; (f) *Distance between blockers and net (BN gap)* – dashed lines represent gaps between blockers and net; (g) *Distance between blockers (B gap)* – dashed lines represent gaps between blockers.

$$v = [(AF - AI)/t],$$

where v was the velocity, AF was the final area (setter–ball contact), AI was the initial area (receiver–ball contact) and t referred to the time between both initial and final areas. (iii) The *variability of the area* [CV(ABO)] was calculated by:

$$CV = s/\bar{x},$$

where CV was the rate of variability (coefficient of variation), s was the standard deviation and \bar{x} was the arithmetic mean of the areas from initial to final moment.

(b) *SBall gap* (Figure 1(b)): (i) *Displacement of the setter to reach the ball* [$d(\text{SBall})$]. It was calculated by the equation:

$$d = 2 \sqrt{(SI_x - SF_x)^2 + (SI_y - SF_y)^2},$$

where d refers to the distance between setter position in the initial (SI) and final (SF) moments of the sequence, according to x and y axes. (ii) The *setter's velocity of displacement* [$v(\text{Sball})$] was calculated through:

$$v = [d/t],$$

where v was the velocity, d was the distance value obtained above and t referred to time of displacement. (iii) The *variability of this gap* [CV(Sball)] was calculated by:

$$CV = s/\bar{x},$$

where CV was the rate of variability (coefficient of variation), s was the standard deviation and \bar{x} was the arithmetic mean of the setter positions from initial to final moment, considering all frames.

(c) *SN gap* (Figure 1(c)): (i) *Distance between setter and net in the initial and final moments of the sequence* [$d(\text{SN}) I$, $d(\text{SN}) F$]. This was calculated by the equation:

$$d = 2 \sqrt{(S_x - N_x)^2 + (S_y - N_y)^2},$$

where d refers to the distance between setter (S) and net (N), according to x and y axes.

(d) *P gap* (Figure 1(d)): (i) *Pass distance – displacement of the ball from receiver to setter* [$d(P)$]. This was calculated by the equation:

$$d = 2 \sqrt{(R_x - S_x)^2 + (R_y - S_y)^2},$$

where d refers to the distance between receiver (R) to setter (S), according to x and y axes. (ii) The *pass velocity* [$v(P)$] was calculated through:

$$v = [d/t],$$

where v was the velocity, d was the distance value obtained above and t referred to time of displacement.

- (e) *SBlock gap* (Figure 1(e)): (i) *Distance between setter and blockers for the three possible blockers in the play (i.e. 2, 3, and 4 positions,) in the initial and final moments of the sequence* [$d(\text{SBlock } 2) \text{ I/F}$, $d(\text{SBlock } 3) \text{ I/F}$, $d(\text{SBlock } 4) \text{ I/F}$]. It was calculated by the equation:

$$d = 2 \sqrt{(S_x - B_x)^2 + (S_y - B_y)^2},$$

where d refers to the distance between setter (S) and blocker (B), according to x and y axes.

- (ii) The approach/separation *velocity between setter and blockers* [$v(\text{SBlock } 2)$, $v(\text{SBlock } 3)$, $v(\text{SBlock } 4)$] was calculated through:

$$v = [(dF - dI)/t],$$

where v was the velocity, dF was the final distance, dI was the initial distance and t referred to time between two moments. (iii) The *variability of this gap* [$CV(\text{SBlock } 2)$, $CV(\text{SBlock } 3)$, $CV(\text{SBlock } 4)$] was calculated by:

$$CV = s/\bar{x},$$

where CV was the rate of variability (coefficient of variation), s was the standard deviation and \bar{x} was the arithmetic mean of the distances from initial to final moment.

- (f) *BN gap* (Figure 1(f)): (i) *Distance between blockers and net for the three possible blockers in the play (i.e. 2, 3, and 4 positions,) in the initial and final moments of the sequence* [$d(\text{BN } 2) \text{ I/F}$, $d(\text{BN } 3) \text{ I/F}$, $d(\text{BN } 4) \text{ I/F}$]. This was calculated by the equation:

$$d = 2 \sqrt{(B_x - N_x)^2 + (B_y - N_y)^2},$$

where d refers to the distance between blocker (B) and net (N), according to x and y axes.

- (g) *B gap* (Figure 1(g)): (i) *Distance between blockers for the three possible blockers in the play (i.e. 2, 3, and 4 positions,) in the initial and final moments of the sequence* [$d(\text{B } 2-3) \text{ I/F}$, $d(\text{B } 3-4) \text{ I/F}$]. This was calculated by the equation:

$$d = 2 \sqrt{(B1_x - B2_x)^2 + (B1_y - B2_y)^2},$$

where d refers to the distance between a blocker (B1) and the next blocker (B2), according to x and y axes. (ii) The approach/separation *velocity between blockers* [$v(\text{B } 2-3)$, $v(\text{B } 3-4)$] was calculated through:

$$v = [(dF - dI)/t],$$

where v was the velocity, dF was the final distance, dI was the initial distance and t referred to time between two moments. (iii) The *variability of this gap* [$CV(B\ 2-3)$, $CV(B\ 3-4)$] was calculated by:

$$CV = s/\bar{x},$$

where CV was the rate of variability (coefficient of variation), s was the standard deviation and \bar{x} was the arithmetic mean of the distances from initial to final moment.

The 37 variables described above are summarised in the Table 1.

Tips can be considered terminal actions, because they try to get a score or make difficult the actions of the opposite team (Palao et al., 2007). The *effectiveness of the tips* was another variable considered for analysis, as the result of the tip could reflect a spatiotemporal configuration of the defence. It was classified as an effective tip the action responsible for the end of the rally, i.e. when the ball contacted the ground directly, resulting in a score. Conversely, a non-effective tip was that defended by the opposite team.

Table 1. Summary of the 37 spatiotemporal variables (gaps).

	Variables	Description
1	(ABO) I	Area between opponents in the initial moment
2	(ABO) F	Area between opponents in the final moment
3	v(ABO)	Changing velocity of the area
4	CV(ABO)	Variability of the area
5	d(SBall)	Displacement of the setter to reach the ball
6	v(SBall)	Setter's velocity of displacement to reach the ball
7	CV(SBall)	Variability of displacement of the setter to reach the ball
8	d(SN) I	Distance between setter and net in the initial moment
9	d(SN) F	Distance between setter and net in the final moment
10	d(P)	Pass distance – displacement of the ball from receiver to setter
11	v(P)	Pass velocity
12	d(SBlock2) I	Distance between setter and blocker 2 in the initial moment
13	d(SBlock 2) F	Distance between setter and blocker 2 in the final moment
14	d(SBlock 3) I	Distance between setter and blocker 3 in the initial moment
15	d(SBlock 3) F	Distance between setter and blocker 3 in the final moment
16	d(SBlock 4) I	Distance between setter and blocker 4 in the initial moment
17	d(SBlock 4) F	Distance between setter and blocker 4 in the final moment
18	v(SBlock 2)	Approach/separation velocity between setter and blocker 2
19	v(SBlock 3)	Approach/separation velocity between setter and blocker 3
20	v(SBlock 4)	Approach/separation velocity between setter and blocker 4
21	CV(SBlock 2)	Variability of approach/separation between setter and blocker 2
22	CV(SBlock 3)	Variability of approach/separation between setter and blocker 3
23	CV(SBlock 4)	Variability of approach/separation between setter and blocker 4
24	d(BN 2) I	Distance between blocker 2 and net in the initial moment
25	d(BN 2) F	Distance between blocker 2 and net in the final moment
26	d(BN 3) I	Distance between blocker 3 and net in the initial moment
27	d(BN 3) F	Distance between blocker 3 and net in the final moment
28	d(BN 4) I	Distance between blocker 4 and net in the initial moment
29	d(BN 4) F	Distance between blocker 4 and net in the final moment
30	d(B 2-3) I	Distance between blockers 2 and 3 in the initial moment
31	d(B 2-3) F	Distance between blockers 2 and 3 in the final moment
32	d(B 3-4) I	Distance between blockers 3 and 4 in the initial moment
33	d(B 3-4) F	Distance between blockers 3 and 4 in the final moment
34	v(B 2-3)	Approach/separation velocity between blockers 2 and 3
35	v(B 3-4)	Approach/separation velocity between blockers 3 and 4
36	CV(B 2-3)	Variability of approach/separation between blockers 2 and 3
37	CV(B 3-4)	Variability of approach/separation between blockers 3 and 4

2.3. Statistical procedures

Firstly, a multivariate analysis of variance (MANOVA) was run to compare tip x sets, by considering 37 dependent variables and 2 actions (86 tips and 86 sets), including the comparison between male and female actions. However, results showed non-significant effects for the interaction between male x female actions [Wilks' Lambda = 0.87, $F_{37,132} = 0.53$, $p = .99$, $\eta p^2 = .13$], which supported the same analysis not considering the sex.

Then, a MANOVA was run to compare tip x sets by considering 37 dependent variables and two actions (86 tips and 86 sets). The 37 variables consisted of those main 7 described above and the velocity and variability of those measures, when appropriate (Table 1).

Considering the significant variables obtained in this first analysis, a second MANOVA was run to explore the effectiveness of the tips. This complementary analysis compared 41 effective tips and 37 non-effective tips by considering 9 dependent variables. In both analyses, the observed significant effects were followed up by use of univariate analysis (ANOVAs) with Bonferroni correction. For all analyses, the level of significance was set at $p < 0.05$, using SPSS software version 21.0.

3. Results

3.1. Tip vs. set analysis

Results showed significant effects for action (tip vs. set) [Wilks' Lambda = 0.59, $F_{37,134} = 2.47$, $p = .001$, $\eta p^2 = 0.406$]. As Table 2 shows, the univariate analyses revealed effects for (ABO) F, $d(SBall)$, $v(SBall)$, $d(SN) I$, $d(SN) F$, $v(P)$, $d(SBlock 2) F$, $d(SBlock 3) F$, $d(SBlock 4) F$ and $v(B 3-4)$.

It was verified that the tips had final areas (ABO) smaller ($M = 20.7 \text{ m}^2$) than sets ($M = 22.5 \text{ m}^2$) (Figure 2 – (i)); the displacement of the setter to reach the ball [$d(SBall)$] was smaller in tips ($M = 1.14 \text{ m}$) than in sets ($M = 1.64 \text{ m}$), and the displacement velocity [$v(SBall)$] was also smaller in tips ($M = 0.8 \text{ m/s}$) than in sets ($M = 1 \text{ m/s}$) (Figure 2 – (iii)); the distance between setter and net in the initial moment [$d(SN) I$] was smaller in tips ($M = 0.79 \text{ m}$) than in sets ($M = 1.03 \text{ m}$), and the distance between setter and net in the final moment [$d(SN) F$] was also smaller in tips ($M = 0.61 \text{ m}$) than in sets ($M = 1.58 \text{ m}$) (Figure 2 – (iv)); the pass velocities [$v(P)$] were larger in tips ($M = 3.5 \text{ m/s}$) than in sets ($M = 3 \text{ m/s}$) (Figure 2 – (ii)); the final distances between setter and the three possible blockers (position 2 – [$d(SBlock 2) F$], position 3 – [$d(SBlock 3) F$] and position 4 – [$d(SBlock 4) F$]) were smaller in tips than in sets, respectively: ($M = 3.98 \times 4.56 \text{ m}$), ($M = 1.88 \times 2.72 \text{ m}$) and ($M = 1.60 \times 2.54 \text{ m}$) (Figure 2 – (v)). All the ANOVA results showed low effects.

The approach/separation velocity between the blockers of positions 3 and 4 [$v(B 3-4)$] showed significance at $p < .05$. However, this result was not considered, because homogeneity of variance for this variable could not be assumed from Levene test. In this case, it is suggested to consider results at below level, as $p < .001$.

In sum, the results show that tips were different from sets, i.e. the two actions were executed due to different values of spatial and/or temporal variation of the five aforementioned variables, with moderate effect. The decision to tip was influenced by mean values of these specific gaps:

- (1) final area between opponents [(ABO) F] = 20.7 m^2 ;

Table 2. Univariate analysis (ANOVAs) results for action (tip x set), considering each variable individually (37 gaps).

	Variables	ANOVA
1	(ABO) I	$F_{1,170} = 0.59, p = 0.44, \eta p^2 = 0.003$
2	(ABO) F*	$F_{1,170} = 6.41, p = 0.01, \eta p^2 = 0.036^*$
3	v(ABO)	$F_{1,170} = 3.02, p = 0.08, \eta p^2 = 0.017$
4	CV(ABO)	$F_{1,170} = 1.95, p = 0.16, \eta p^2 = 0.011$
5	d(SBall)*	$F_{1,170} = 13.08, p = 0.00, \eta p^2 = 0.071^*$
6	v(SBall)*	$F_{1,170} = 9.21, p = 0.00, \eta p^2 = 0.051^*$
7	CV(SBall)	$F_{1,170} = 0.04, p = 0.84, \eta p^2 = 0.000$
8	d(SN) I*	$F_{1,170} = 5.14, p = 0.03, \eta p^2 = 0.029^*$
9	d(SN) F*	$F_{1,170} = 74.34, p = 0.00, \eta p^2 = 0.304^*$
10	d(P)	$F_{1,170} = 2.90, p = 0.09, \eta p^2 = 0.017$
11	v(P)*	$F_{1,170} = 11.10, p = 0.00, \eta p^2 = 0.061^*$
12	d(SBlock2) I	$F_{1,170} = 0.56, p = 0.46, \eta p^2 = 0.003$
13	d(SBlock 2) F*	$F_{1,170} = 10.90, p = 0.00, \eta p^2 = 0.060^*$
14	d(SBlock 3) I	$F_{1,170} = 0.21, p = 0.65, \eta p^2 = 0.001$
15	d(SBlock 3) F*	$F_{1,170} = 31.72, p = 0.00, \eta p^2 = 0.157^*$
16	d(SBlock 4) I	$F_{1,170} = 0.27, p = 0.60, \eta p^2 = 0.002$
17	d(SBlock 4) F*	$F_{1,170} = 45.74, p = 0.00, \eta p^2 = 0.212^*$
18	v(SBlock 2)	$F_{1,170} = 0.01, p = 0.93, \eta p^2 = 0.000$
19	v(SBlock 3)	$F_{1,170} = 0.01, p = 0.91, \eta p^2 = 0.000$
20	v(SBlock 4)	$F_{1,170} = 0.92, p = 0.34, \eta p^2 = 0.005$
21	CV(SBlock 2)	$F_{1,170} = 0.05, p = 0.83, \eta p^2 = 0.000$
22	CV(SBlock 3)	$F_{1,170} = 0.94, p = 0.33, \eta p^2 = 0.006$
23	CV(SBlock 4)	$F_{1,170} = 1.80, p = 0.18, \eta p^2 = 0.010$
24	d(BN 2) I	$F_{1,170} = 0.68, p = 0.41, \eta p^2 = 0.004$
25	d(BN 2) F	$F_{1,170} = 1.85, p = 0.18, \eta p^2 = 0.011$
26	d(BN 3) I	$F_{1,170} = 0.04, p = 0.84, \eta p^2 = 0.000$
27	d(BN 3) F	$F_{1,170} = 0.01, p = 0.91, \eta p^2 = 0.000$
28	d(BN 4) I	$F_{1,170} = 0.80, p = 0.37, \eta p^2 = 0.005$
29	d(BN 4) F	$F_{1,170} = 0.35, p = 0.55, \eta p^2 = 0.002$
30	d(B 2-3) I	$F_{1,170} = 2.24, p = 0.14, \eta p^2 = 0.013$
31	d(B 2-3) F	$F_{1,170} = 0.46, p = 0.50, \eta p^2 = 0.003$
32	d(B 3-4) I	$F_{1,170} = 1.55, p = 0.22, \eta p^2 = 0.009$
33	d(B 3-4) F	$F_{1,170} = 2.26, p = 0.14, \eta p^2 = 0.013$
34	v(B 2-3)	$F_{1,170} = 0.02, p = 0.90, \eta p^2 = 0.000$
35	v(B 3-4)*	$F_{1,170} = 4.26, p = 0.04, \eta p^2 = 0.024^*$
36	CV(B 2-3)	$F_{1,170} = 0.55, p = 0.46, \eta p^2 = 0.003$
37	CV(B 3-4)	$F_{1,170} = 0.92, p = 0.34, \eta p^2 = 0.005$

*Significant effects.

- (2) (i) displacement of the setter to reach the ball [$d(SBall)$] = 1.14 m;
(ii) displacement velocity of the setter to reach the ball [$v(SBall)$] = 0.8 m/s;
- (3) (i) distance between setter and net in the initial moment [$d(SN) I$] = 0.79 m;
(ii) distance between setter and net in the final moment [$d(SN) F$] = 0.61 m;
- (4) pass velocity [$v(P)$] = 3.5 m/s;
- (5) (i) final distance between setter and blocker 2 [$d(SBlock 2) F$] = 3.98 m;
(ii) final distance between setter and blocker 3 [$d(SBlock 3) F$] = 1.88 m;
(iii) final distance between setter and blocker 4 [$d(SBlock 4) F$] = 1.60 m.

3.2. Effectiveness of the tips analysis

From 86 tips, 48% were effective, while 52% were non-effective. This proportion was similar, with 41 effective tips (20 male and 21 female) and 45 non-effective tips (23 male and 22

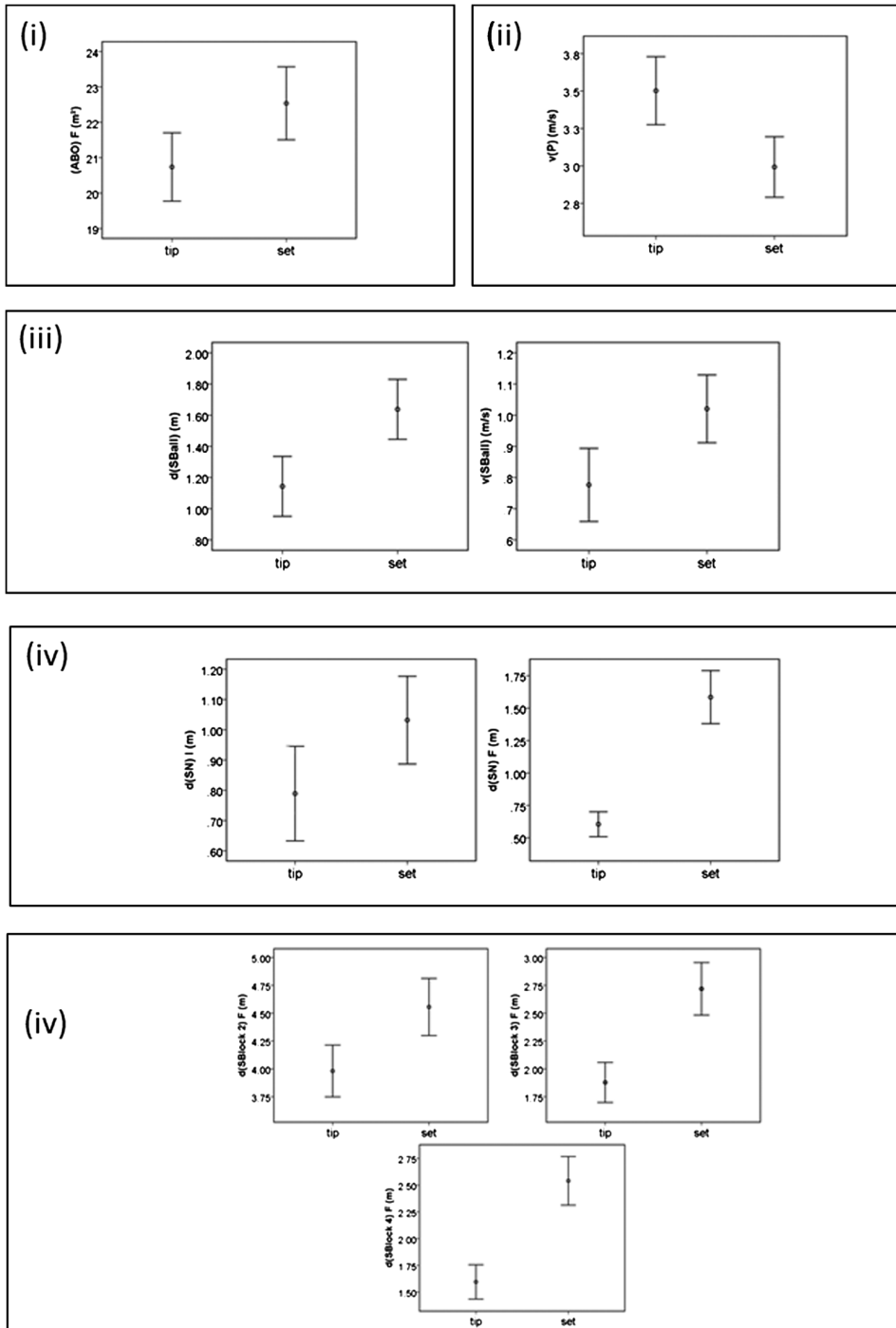


Figure 2. (i) Mean of final areas – $(ABO) F (m^2)$ in tips and sets. (ii) Mean of pass velocities – $v(P) (m/s)$ in tips and sets. (iii) Mean of setter displacements (m) to reach the ball – $d(SBall)$ – and displacement velocities (m/s) – $v(SBall)$ – in tips and sets. (iv) Mean of initial distances (m) – $d(SN) I$ – and final distances – $d(SN) F$ – between setter and net in tips and sets. (v) Mean of final distances (m) between setter and the three blockers (2, 3 and 4 positions), respectively – $d(SBlock 2) F$, $d(SBlock 3) F$ and $d(SBlock 4) F$ in tips and sets. Vertical bars show .95 confidence interval.

female). A possible mean of this descriptive result might be a different game configuration, according the effectiveness of the defence, which was verified in this second analysis. Results showed non-significant effects [Wilks' Lambda = 0.90, $F_{9,68} = 0.85$, $p = 0.57$, $\eta p^2 = 0.101$], which means that the nine significant variables from the first analysis were not significant to distinguish effective tips from non-effective tips.

4. Discussion

The aim of this study was to investigate the volleyball setter's decision-making on tipping, based on spatiotemporal variables involving the interaction between players and between players and the game environment.

Five variables were critical for the setter to tip the ball, because they were different from those of when sets occurred. Therefore, specific interactions may have influenced the setter's decision to tip. Notably, in the attacking team's court (setter's team), these were the conditions: the setter was 0.79 m near the net, and the pass was fast (3.5 m/s), leading him to move about 1.14 m at 0.8 m/s to reach the ball, approximating himself even more with the net (0.61 m). At the same time, these were the conditions in the defending team's court: the setter's displacement approximated him to blockers 2, 3 and 4, respectively (3.98, 1.88 and 1.60 m) simultaneously so that blockers created with the other defenders an area of 20.7 m² (spatial interactions). This was the game scenario in the moment the setter touched the ball.

So, when setters were near the net and received faster passes, they had to move short distances and not so fast to approximate even more with the net. This could have facilitated his perception about game configuration in the opposite court, leading him to tip the ball. This opposite configuration was characterised by the setter's approach with the three blockers in the moment he touched the ball, at the same time that the blockers created small areas with the other defenders, compared to sets.

Setters near the net in the initial moment probably meant that they began the action in ideal position. High-speed passes received could have meant difficulty to set the ball properly, and consequently, facility to tip the ball. Another hypothesis is that those passes have benefited fewer chances for the defending team to position, if the tip occurred, as plays with slow attack time foster anticipation, decision-making and defenders' moves (García-de-Alcaraz, Ortega, & Palao, 2016).

The small displacement, consequently, at low speed, could have indicated that setters were well placed and would receive precise passes. The proximity to the net in the final moment could have indicated fewer chances that the ball would not cross the net with the tip or better conditions for setters to redirect their action. The accuracy of the tip, as well as the accuracy of passes (Barsingerhorn, Zaal, de Poel, & Pepping, 2013), would decrease with increasing distance to be covered by the setter. It is important to highlight that this variable had a larger significant effect compared to all of the others, even though its effect had been approximately moderate (see Table 2).

The game configuration in the opposite court was arranged by the setter's approach with the three blockers and the smaller final area, allowing the interpretation that this area was more regular, formed by players near each other. That is, players were not well distributed on the court, resulting in larger gaps between players and between players and the court delimitation, causing difficulty in defending the tip. Otherwise, large areas could have meant

players distributed on the court, covering more spaces, not making clear gaps, inspiring the setter to tip the ball.

Results confirmed the established hypothesis with a moderate effect, showing with low effects that tips were influenced by specific values of spatial and spatiotemporal gaps, in relation to the attacking team, and only spatial, in relation to the defending team. For the attacking team, the variables were: initial and final distances between setter and net [$d(SN) I$ and $d(SN) F$], distance and velocity between setter and ball [$d(SBall)$ and $v(SBall)$], and pass velocity [$v(P)$]. For the defending team, the variables were: final area between opponents [(ABO) F] and final distance between setter and blockers [$d(SBlock 2) F$, $d(SBlock 3) F$ and $d(SBlock 4) F$].

These findings corroborate the proposition of spatial and spatiotemporal measures to act as informational variables for decision-making (Corrêa, Davids, et al., 2014; Corrêa, Vilar, et al., 2012; Corrêa, Vilar, Davids, & Renshaw, 2014; Passos et al., 2008; Passos, Araújo, Davids, Gouveia, Milho, et al., 2009b; Passos, Araújo, Davids, Gouveia, Serpa, et al., 2009a; Travassos, Araújo, Duarte, et al., 2012; Vilar, Araújo, Davids, Correia, & Esteves, 2012). From a systemic point of view, it is reasonable to infer that the interaction with this set of information (significant gaps) may have implied only a pattern of information representing the global game configuration (Corrêa, Alegre, et al., 2012). That is, it is possible to argue that tips occurred under influence of perception of this game configuration, which was presented through a certain pattern of spatial and spatiotemporal characteristics between teams. It should be highlighted that game patterns configuration and pattern transitions, which are influenced by relations between players and between players and their game environment, characterise ecological dynamics (Araújo et al., 2006).

Game patterns in volleyball were also revealed comprehending spatial and temporal measures, such as setting zone and type of set, respectively, specifically in relation to the occurrence of quick sets (Afonso, Mesquita, Marcelino, & Da Silva, 2010). Players' perception, especially from experts, is characterised by this pattern recognition and its utilisation for anticipation, based on visual cues (Janelle & Hillman, 2003). The pattern to set off tips emerged from game dynamics, in two levels of analysis, as suggested by McGarry et al. (2002): due to players' coordination and teams' coordination.

The relation between ball and net, as well as defending players, can be understood as a system sub phase (Passos, Davids, et al., 2011). Both constituted the pattern of interaction between teams, which afforded the possibility for the tip to occur. Setters perceived opportunities to tip the ball instead of setting it to an attacker, in consequence of interactions between: setter and ball (extrapersonal – object), setter and net (extrapersonal – place), setter and blockers (interpersonal), and defenders (interpersonal). This kind of coordination pattern of collective behaviour that reflects interactions between players, place and object was also found in studies involving invasion team sports (Vilar, Araújo, Davids, & Travassos, 2012).

It is important to highlight that defending teams, perceiving the coordination between setter and ball and setter and net, could try to anticipate the defence of the tips. However, the similar proportion of effective (48%) and non-effective tips (52%) shows the difficulty to oppose other unpredictable aspects involving the tips, such as its direction. That way, it is emphasised that the unpredictable nature of the tips seems to guarantee the perturbation of the stability of the system. The system demands self-organisation to re-establish the order

after the tip, independently of the opponent's defence; i.e. the tip as a critical incident or not (Hughes et al., 1998).

From the results, one can affirm that the dynamic context of the game offered action possibilities for the setter's decision-making of tipping the ball. These possibilities were characterised by the interaction between teams, particularly by the combination between spatiotemporal gaps constituted by the setter's team, concomitantly with a combination of spatial gaps constituted by the opponents' team. The setter, perceiving his relation with the ball and net, showed that he perceived his relation with blockers, and the relation between blockers and the other defenders. This perception of the game environment seems to determine his decision to tip the ball.

Interestingly, regarding interpersonal coordination, the interaction between the setter and the blocker in the 4 position, was crucial to this decision, as the distance between them was frequently smaller compared to the other blockers, acting as a control parameter for the tip situation. Indeed, the literature has considered as critical aspects those that cause change in the system (Corrêa, Davids, et al., 2014; Corrêa, Vilar, et al., 2012; Corrêa, Vilar, et al., 2014). It is possible to say that the blocker in the 4 position was nearest to the setter, and the blocker in the 2 position was farther from the setter, which characterised an open position, indicating the setter an opportunity to perform the tip (Queiroga, Matias, Mesquita, & Greco, 2010).

Even with the net between teams causing the opposition of the teams in distinct courts, these results showed similar measures compared to invasion sports studies, for instance, as interpersonal distance (Passos et al., 2008; Passos, Milho, et al., 2011), extrapersonal distance (Vilar, Araújo, Davids, & Travassos, 2012) and area (Corrêa, Vilar, et al., 2014).

Finally, studies developed under ecological dynamics have revealed that the perception of interactions involving players in their game environment, through spatial and spatiotemporal variables, is crucial to decision-making in sports. Such interactional measures are characterised as a control parameter in decision-making; for this specific study, setters made the decision based on critical values of some investigated measures.

5. Conclusions

Results revealed that spatiotemporal variables of interpersonal and extrapersonal coordination were crucial for a setter's decision-making of performing the tip, highlighting the relation between the two teams. It follows that tips and sets occurred in different conditions. Therefore, the interactions between players and teams, including regarding the net as a link between teams (together with the ball), were revealed to characterise the spatial and spatiotemporal relations that occur in the team sport of volleyball, influencing the setter specific decision to tip the ball.

These conclusions are delimited to the analysis of the players' displacements in the x and y axes, although all the spatiotemporal relations have considered the projection of the players on the ground while they were off the ground (z axis). The use of TACTO software as the tool to capture the measures that reflect the environmental sports context interactions has provided enough support to the development of the studies, considering its limitations.

Further research could include other coordination variables, for instance, a measure clearly reflecting other gaps in the court, such as the precise area formed by players and the lines constraining the volleyball court. Another one would be the way to tip in terms

of direction and velocity. Future studies could also consider contextual variables such as the status of the match, game complex, the set and the moment of the set in which the tips occur. To explore the volleyball game interactions, other decisions could be investigated, such as tips performed by spikers instead of attacking the ball, as well as the decision of passers to receive the service, studied by Denardi et al. (2017). Moreover, in order to find larger statistical effects, the sample could be increased.

It is possible to conjecture that professionals could instruct the setters to stay near the net and to be alert to pass velocity and distance, while at the same time being alert to blockers and to the opposite area in deciding to tip or to set the ball. However, more studies are needed to generate more evidence and to consolidate the knowledge produced in the present study to guide practical implications.

Disclosure statement

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