ORIGINAL ARTICLE

The interpersonal coordination constraint on the volleyball setter's decision-making on setting direction

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ABSTRACT

This study investigated the setter's decision-making on setting direction based on interpersonal (interaction between players) and extra personal (interaction between players and some place or object) coordination. The sample consisted of 86 sequences of play involving settings performed by males (n = 43) and females (n = 43). Fifty-nine spatiotemporal measures of interpersonal and extra personal coordination were obtained from the x and y coordinates of volleyball players' displacements using the TACTO software. Settings to each court zone were compared in relation to each spatiotemporal measure. Results showed that when the final area between attacker in the zone 3 and block was greatest and emerged from highest velocity, setters decided to set to zone 2. On the other hand, when the foregoing area was smallest and emerged from lowest velocity, setters decided to set to zones 3 and 4. It was concluded that the final area between attacker in the zone 3 and block and its emerging velocity constrained the setters' decision-making on setting direction. This study provides useful insights into the design of practice tasks in volleyball, suggesting that setters should be advised to be attuned to the interpersonal coordination involving attacker in the zone 3 and block.

Keywords: Performance analysis, Tactical behaviour, Team sport, Spatiotemporal interactions, Game analysis, Motor skill.

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INTRODUCTION

Understanding how volleyball players make decisions has increasingly been the focus of research in the last few years (e.g., Castro et al., 2022; Degrenne et al., 2023; Link & Raab, 2022; Lola & Tzetzis, 2021; Ramos et al., 2022; Suárez et al., 2020). This is because the game dynamic that emerges from the players' simultaneous interactions of cooperation and opposition requires they frequently make decisions as a *sine qua non* for successful performances.

Recently, a set of studies has been developed to comprehend how such decisions are made from an ecological dynamic perspective (e.g., Denardi et al., 2017, 2018, 2023). This implies investigating the team sport of volleyball as a dynamic system functioning at an ecological level of analysis, that is, in the context in which decisions are made (Araújo et al., 2006). The main assumption here is that in such context players make decisions based on constraints (e.g. affordances) emerging from spatiotemporal interpersonal and extra personal coordination (Passos et al., 2014). These coordinations have been referred as dynamic interactions between players and between them and some place or object in game context, respectively (Millar et al., 2013). On this concern, findings have pointed out that setters make decisions on tipping based on the gap size (area) formed by defenders (Denardi et al., 2017b). In addition, they have showed that in attacking phases setters decide to tip based on greater defending area and passing velocity than in counterattacking phase (Denardi et al., 2023).

Notwithstanding the advances in knowledge about the setters' decision-making, where they pass the ball to attack conclusion has been considered their main and most frequent decision-making (Ramos et al., 2017; Silva et al., 2013). This is because such setter's decision-making may generate optimal condition for attacking, which enables uncertainty or perturbation on opponents' responses (Costa et al., 2016; Sotiropoulos et al., 2019). A recent study by Sotiropoulos et al. (2019) investigated the setting zone choices by elite setters by considering the quality of the dig in two game phases: until the second counterattack (complex II) and from the third counterattack (complex III). The dig quality was rated by coaches based in statistical analyses of volleyball team performance. They also categorized the setting choices by considering the consequent attacking zone. Results showed that in the complex II, most digs were evaluated as good and related to the ball distribution to the zone 4. Differently, in the complex III many digs were of moderate quality. However, they were also related to the choice of zone 4 for male and zones 4 and 2 for females.

The present study aimed to extend the current findings about setters' decision-making on setting direction based on the interpersonal and extra personal coordinations. It appeared reasonable to consider that, similarly to several team sports, physical variables representing information emerging from players interactions could constrain the setter's decision-making on setting direction to different court zones.

METHOD

Sample

The sample consisted of 86 sequences of play involving settings performed by males (n = 43) and females (n = 43). They were randomly selected 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 participated about 6 male and 10 female teams, approximately 190 players and 30 setters. The research protocol was given ethical approval by the local Institutional Review Board.

Procedures

The sequences of the game were randomly 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. 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 players were edited through TACTO software (Duarte et al., 2010; Fernandes et al., 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 RStudio software (2022.02.3 version), from which the following spatiotemporal measures of interpersonal coordination (gaps) (Figure 1) were calculated. These measures were defined based on their importance to setters' decision-making on setting distribution (Denardi et al., 2017b; Gouvêa & Lopes, 2007).

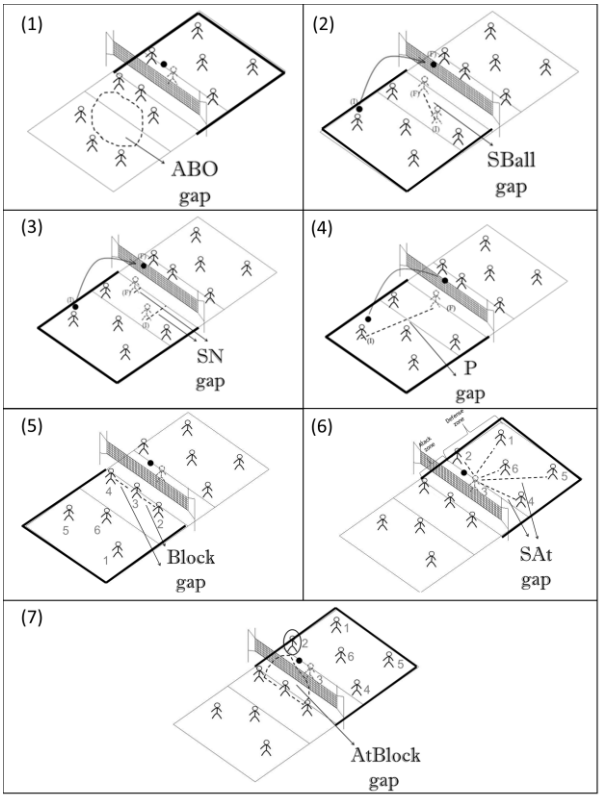

Figure 1. Illustration of spatiotemporal measures of interpersonal and extra personal coordination.

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

$$A = \left|\left(x_1 y_2 - y_1 x_2\right) + \left(x_2 y_3 - y_2 x_3\right) .... + \left(x_n y_1 - y_n x_1\right) / 2\right| ,$$

where x_1 refers to the coordinate *x* of player 1, y_n refers to the coordinate *y* of player *n*, and so on.

(2) *SBall* gap (Figure 1-2): *Displacement of the setter to reach the ball* [*d(SBall)*]. It was calculated by the equation:

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

where *d* refers to the distance between setter position in the initial (SI) and final (SF) moments, according to *x* and *y* axes.

(3) *SN* gap (Figure 1-3): *Distance between setter and net in the initial and final moments* [*d(SN) I, d(SN) F*]. This was calculated by the equation:

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

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

(4) *P* gap (Figure 1-4): *Passing distance – displacement of the ball from receiver to setter* [*d(P)*]. This was calculated by the equation:

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

where *d* refers to the distance between receiver (R) to setter (S), according to *x* and *y* axes.

(5) *Block* gap (Figure 1-5): *Distance between blockers (zones 2, 3, and 4) in the initial and final moments* [*d(Block 2-3) I/F, d(Block 3-4) I/F*]. This was calculated by the equation:

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

where *d* refers to the distance between a blocker (B1) and the next blocker (B2), according to *x* and *y* axes.

(6) *SAt* gap (Figure 1-6): *Distance between setter and attackers (zones 1, 3, 4, 5 and 6) in the initial and final moments* [*d(SAt 1) I/F, d(SAt 3) I/F, d(SAt 4) I/F, d(SAt 5) I/F, d(SAt 6) I/F*]. This was calculated by the equation:

$$d = \sqrt[2]{\left(S_x - At_x\right)^2 + \left(S_y - At_y\right)^2} ,$$

where *d* refers to the distance between setter (S) and attacker (At), according to *x* and *y* axes.

(7) *AtBlock* gap (Figure 1- 7): *Area between attackers in the zones 1, 3, 4, 5 and 6, (named attackers 1, 3, 4, 5, and 6, respectively) and block (zones 2, 3, and 4) in the initial and final moments* [*(At1Block) I/F, (At3Block) I/F, (At4Block) I/F, (At5Block) I/F and (At6Block) I/F*]. This was calculated by the equation:

$$A = \left|(x_1 y_2 - y_1 x_2) + (x_2 y_3 - y_2 x_3) ..... + (x_n y_1 - y_n x_1)/2\right|,$$

where x_1 refers to the coordinate *x* of player 1, y_n refers to the coordinate *y* of player *n*, and so on.

These measures were also analysed in terms of their rates of changing from initial to final moments. For this purpose, the changing velocity was calculated through:

$$v = [(mF - mI) / t],$$

where *v* was the velocity, *mF* was the final value of the measure, *mI* was the initial value of the measure, and *t* referred to time between both initial and final moments. And the *variability* was calculated by:

$$CV = \sigma / \mu$$

where *CV* is the ratio of variability, σ refers to the standard deviation, and μ is the arithmetic mean of the measure from initial to final moment. The foregoing measures are summarized in the Table 1.

Table 1. Summary of the spatiotemporal measures of interpersonal(*) and extra personal(**) coordination.

	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)	Passing distance – displacement of the ball from receiver to setter(*)
11	v(P)	Passing velocity(*)
12	d(B 2-3) I	Distance between blockers 2 and 3 in the initial moment(*)
13	d(B 2-3) F	Distance between blockers 2 and 3 in the final moment(*)
14	d(B 3-4) I	Distance between blockers 3 and 4 in the initial moment(*)
15	d(B 3-4) F	Distance between blockers 3 and 4 in the final moment(*)
16	v(B 2-3)	Velocity of approaching/moving away of blockers 2 and 3(*)
17	v(B 3-4)	Velocity of approaching/moving away of blockers 3 and 4(*)
18	CV(B 2-3)	Variability of approaching/moving away of blockers 2 and 3(*)
19	CV(B 3-4)	Variability of approaching/moving away of blockers 3 and 4(*)
20	d(SAt1) I	Distance between setter and attacker 1 in the initial moment(*)
21	d(SAt1) F	Distance between setter and attacker 1 in the final moment(*)
22	d(SAt3) I	Distance between setter and attacker 3 in the initial moment(*)
23	d(SAt3) F	Distance between setter and attacker 3 in the final moment(*)

24	d(SAt4) I	Distance between setter and attacker 4 in the initial moment(*)
25	d(SAt4) F	Distance between setter and attacker 4 in the final moment(*)
26	d(SAt5) I	Distance between setter and attacker 5 in the initial moment(*)
27	d(SAt5) F	Distance between setter and attacker 5 in the final moment(*)
28	d(SAt6) I	Distance between setter and attacker 6 in the initial moment(*)
29	d(SAt6) F	Distance between setter and attacker 6 in the final moment(*)
30	v(SAt1)	Velocity of approaching/moving away of setter and attacker 1(*)
31	v(SAt3)	Velocity of approaching/moving away of setter and attacker 3(*)
32	v(SAt4)	Velocity of approaching/moving away of setter and attacker 4(*)
33	v(SAt5)	Velocity of approaching/moving away of setter and attacker 5(*)
34	v(SAt6)	Velocity of approaching/moving away of setter and attacker 6(*)
35	CV(SAt1)	Variability of approaching/moving away of setter and attacker 1(*)
36	CV (SAt3)	Variability of approaching/moving away of setter and attacker 3(*)
37	CV (SAt4)	Variability of approaching/moving away of setter and attacker 4(*)
38	CV (SAt5)	Variability of approaching/moving away of setter and attacker 5(*)
39	CV (SAt6)	Variability of approaching/moving away of setter and attacker 6(*)
40	(At1Block) I	Area between attacker 1 and block in the initial moment(*)
41	(At1Block) F	Area between attacker 1 and block in the final moment(*)
42	(At3 Block) I	Area between attacker 3 and block in the initial moment(*)
43	(At3 Block) F	Area between attacker 3 and block in the final moment(*)
44	(At4 Block) I	Area between attacker 4 and block in the initial moment(*)
45	(At4 Block) F	Area between attacker 4 and block in the final moment(*)
46	(At5 Block) I	Area between attacker 5 and block in the initial moment(*)
47	(At5 Block) F	Area between attacker 5 and block in the final moment(*)
48	(At6 Block) I	Area between attacker 6 and block in the initial moment(*)
49	(At6 Block) F	Area between attacker 6 and block in the final moment(*)
50	v(At1 Block)	Changing velocity of the area At1 Block(*)
51	v(At3 Block)	Changing velocity of the area At3 Block(*)
52	v(At4 Block)	Changing velocity of the area At4 Block(*)
53	v(At5 Block)	Changing velocity of the area At5 Block(*)
54	v(At6 Block)	Changing velocity of the area At6 Block(*)
55	CV(At1 Block)	Variability of the area At1 Block(*)
56	CV(At3 Block)	Variability of the area At3 Block(*)
57	CV(At4 Block)	Variability of the area At4 Block(*)
58	CV(At5 Block)	Variability of the area At5 Block(*)
59	CV(At6 Block)	Variability of the area At6 Block(*)

Statistical procedures

An ANOVA was run for each spatiotemporal measure to compare the settings to each zone. As the number of settings was different for each zone, in order to make inferential comparison possible, the *Fdr* method of the function *p.adjust* was used to adjust each ANOVA *p* value. Observed significant effects were followed up by use of Tukey-Kramer post-hoc. The settings of males and females were analysed together because separately there were some conditions which did not allow statistical comparison. For instance, female players performed only 2 settings to zone 1. In addition, there was no setting to zone 6. In sum, the number of settings to zones 1, 2, 3, 4, 5, and 6 were 7, 28, 11, 35, and 5, respectively. For all analyses, the level of significance was set at $p < .05$.

RESULTS

The ANOVAs' results revealed effects only for two spatiotemporal measures: *At3 Block* ($F_{4,81}$ = 7.605, p = .0017, ηp^2 = 0.27) and *vAt3 Block* ($F_{4,81}$ = 5.427, p = .0187, ηp^2 = 0.21). It was verified that in settings to zone 2, the final area between attacker 3 and block *(At3 Block)* was larger (M = 9.58 m^2) than those areas of the zones 1 (M = 5.98 m^2), 3 (M = 5.17 m^2), and 4 (M = 6.85 m^2) (p < .01). It was also revealed that the changing velocity of this same area (*At3 Block*) was larger (M = 2.28 m/s) than those of the zones 3 (M = 0.90 m/s) and 4 (M = 0.24 m/s) (p < .01) (Figure 2).

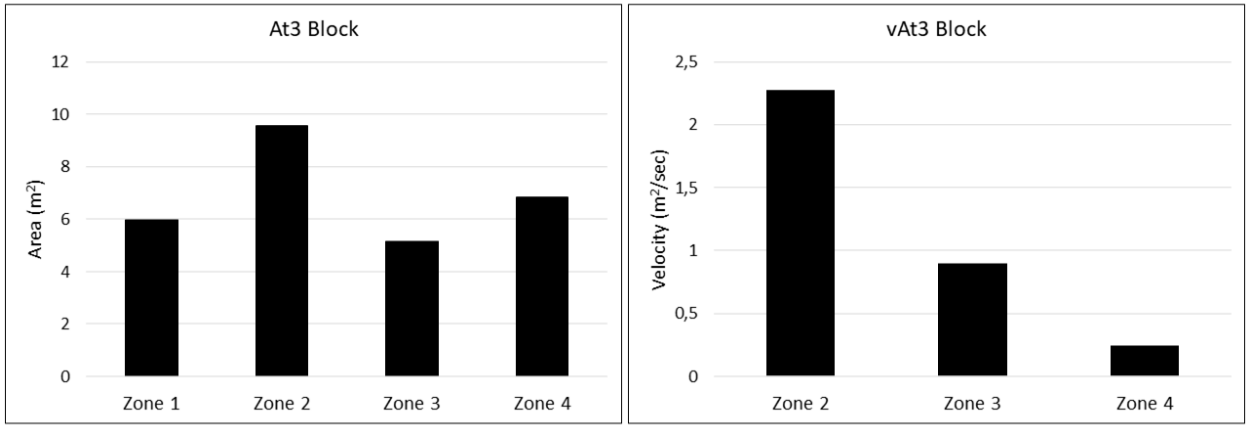

Figure 2. Illustration of difference revealed by the statistical analyses by considering the area (m^2) and area velocity (m^2/sec).

DISCUSSION

This study investigated the volleyball setters' decision-making on setting direction based on physical measures of interpersonal and extra personal coordination. Results showed effects for two interpersonal ones, that is, when the final areas between attacker 3 and block were greatest and they emerged from highest velocity, setters decided to set to zone 2. In an opposite vein, when the final areas between attacker 3 and block were smallest and they emerged from lowest velocity, setters made the decision to set to zones 3 and 4.

It is possible that, when setters decided to set to zone 2 (where opposite and middle hitters played), attacker 3 and block were further away each other in the moment of the setting. The fast velocity culminating in a greater area involving the block probably occurred because the middle hitters were preparing an attack in a fast tempo, which did not allow a double or triple block formation (Afonso et al., 2005; Costa et al., 2016; Marcelino et al., 2014; Tsavdaroglo et al., 2018). Conversely, when setters decided to set to zones 3 and 4, attacker 3 and block were closer each other in the moment of the setting, and this area, from receiver to setter, slowly changed, compared to zone 2.

It can also be thought that the slow velocities could be related to middle hitter and block, which were already positioned in their cover zones. And the fast velocities could mean that these players were organising themselves for an unusual play, with the middle hitter carrying out a one-leg attack, when the setter was in the front court (Palao et al., 2007). In this last scenario, the block formation is made difficult, being easier to be explored.

In addition, it is possible that the fast middle hitters' displacement resulting in a gap between them and block constrained setters to pass the ball to a zone where block would not be well-positioned (zone 2), compared to the other settings when they were in the front court (zones 3 and 4). Indeed, the setter aims to build favourable block situations to hitters (Matias & Greco, 2012). For instance, Castro and Mesquita (2008) suggest that the exploration of the zone 4 external offensive space allows the attacker to take advantage over opponent block, not only because of the most block displacement demand, but because in this zone is positioned the poor blocker, the setter.

These findings provide support for ecological dynamics perspective's propositions about physical variables of players interaction functioning as constraints on volleyball players' decision-making (e.g., Denardi et al., 2017, 2018, 2023). Specifically, the area and its emerging velocity represented a kind of collective behaviour involving attacker and defenders interactions that constrained setter's decision-making.

It is interesting to note that, unlike other team sports, the variability of interactions between volleyball players did not function as an informational variable constraining the setters' decision-making. For instance, studies have shown that in the team sport of futsal the variability of players' interpersonal coordination plays important role in the successful decision making (Corrêa eta al., 2016, 2020). Given the importance of variability in the performance of motor skills (Corrêa et al., 2015), its role in volleyball players' decision-making should be further investigated.

In summary, the results of this study allow us to conclude that the final area between attacker 3 and block and its velocity constrained the setters' decision-making on ball distribution to different court zones. This study provides useful insights into the design of practice tasks in volleyball, suggesting that setters should be advised to be attuned to the interpersonal coordination involving attacker 3 and block. Future studies should investigate such decision-making by considering the different game stages (throughout the sets) and status (when the team is winning and losing).

AUTHOR CONTRIBUTIONS

Renata Alvares Denardi: contributed to all stages of research development. Fabian Alberto Romero Clavijo: contributed mainly to the elaboration of the method and analysis of the results. Tatyane De Souza Santana: mainly contributed to data collection and text review. Thiago Augusto Costa De Oliveira: mainly contributed to the elaboration of the method and analysis of the results. Umberto Cesar Corrêa: contributed to analysing the results and writing the article.

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DISCLOSURE STATEMENT

No potential conflict of interest were reported by the authors.

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