

SPACE CONFIGURATION AND NUMERICAL RELATIONSHIP
DURING PROFESSIONAL SOCCER MATCHES: A PROPOSAL
FOR SMALL-SIDED GAMES DESIGN

original paper

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ABSTRACT

Purpose. The purpose of this study was to analyse the most recurrent characteristics of soccer attacking sequences regarding the effective space available, the numerical relationship, and the distance between the defensive line and the goal.**Methods.** Overall, 4 Brazilian professional matches were recorded and the trajectories of 101 players were obtained by a tracking method. The variables of the studies were: length (the distance between 2 more distant players, longitudinally), width (the distance between 2 more distant players, laterally), numerical relationship (the number of attacking players vs. the number of defending players inside a given area), and the distance to the goal (the distance between the defensive player closer the goal line and the goal line).**Results.** The mean values and standard deviations were 24.59 (\pm 13.40) m for the length, 44.13 (\pm 12.51) m for the width, and 29.19 (\pm 11.40) m for the distance to goal line. A match was characterized mostly by the interaction among a large number of players ($p < 0.001$). The length, width, and distance to goal line changed depending on the numerical relationship. However, the effective space available was characterized by the width, being greater than the length, and the game had more situations of defensive numerical superiority, followed by the numerical equality ($p < 0.001$).**Conclusions.** The study presented insights regarding strategies for soccer games that can guide coaches in the design of training drills in accordance with real situations in a soccer match.**Key words:** match analysis, small-sided games, football, tactics, training, team sports

Introduction

Small-sided games (SSGs) are constantly used by coaches as part of a regular training program during the season, and are characterized by a reproduction of a soccer match but with a lower number of players, smaller effective space, and often different rules [1]. SSGs improve the physical, technical, and tactical dimension simultaneously [2]. Recently, studies have focused on the effects of different SSG formats and task conditions on changes in the physiological [1, 3–5],

technical [3, 4, 6], physical [7, 8], and tactical performance [4, 6, 9, 10], on manipulating the space, the number of players, the number of ball touches per player [1, 4–7, 9–12], and on the impact of training programs involving SSGs [5, 12].

By analysing the space control during a match, many variables have been reported, such as length (the distance between the 2 more distant players, longitudinally, without goalkeepers), width (the distance between the 2 more distant players, laterally, without goalkeepers), the area (formed by the width and length),

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the numerical relationship (the number of attacking players vs. the number of defending players inside a given area), and individual playing area (IPA) (obtained by dividing the area among the players) [13–15].

With the purpose of better explaining the subgroups (interaction of given players, such as attackers and defenders closer to the ball) during a match, Gonçalves et al. [16] introduced the notion of an effective playing space (the smallest polygonal area delimited by the peripheral outfield players) for groups of 3–10 players. Aiming to design training drills with similar characteristics to playing spaces, Caro et al. [17] presented the length, width, and IPA considering the 4 and the 7 nearest players of both teams.

The SSG models described in literature usually involve the goalkeeper inside the designed area [1, 5, 8,

12]. However, during a match, there is an additional area between the goal line and the nearest defender, which is associated with the defence behaviour [13, 15]. Furthermore, the numerical relationship during a match was reported in the studies by Clemente et al. [18] and Vilar et al. [19].

The described studies provided important insights related to the tactical features of SSGs and official soccer matches. In addition, recent studies have shown that junior and senior players did not present differences in physiological responses or technical actions, proving that for SSG design, players are expected to behave in a similar manner, regardless of the level [3]. However, when planning SSG protocols, the choice of the area of play and the number of players involved were arbitrary defined in most of the studies. Usually, the

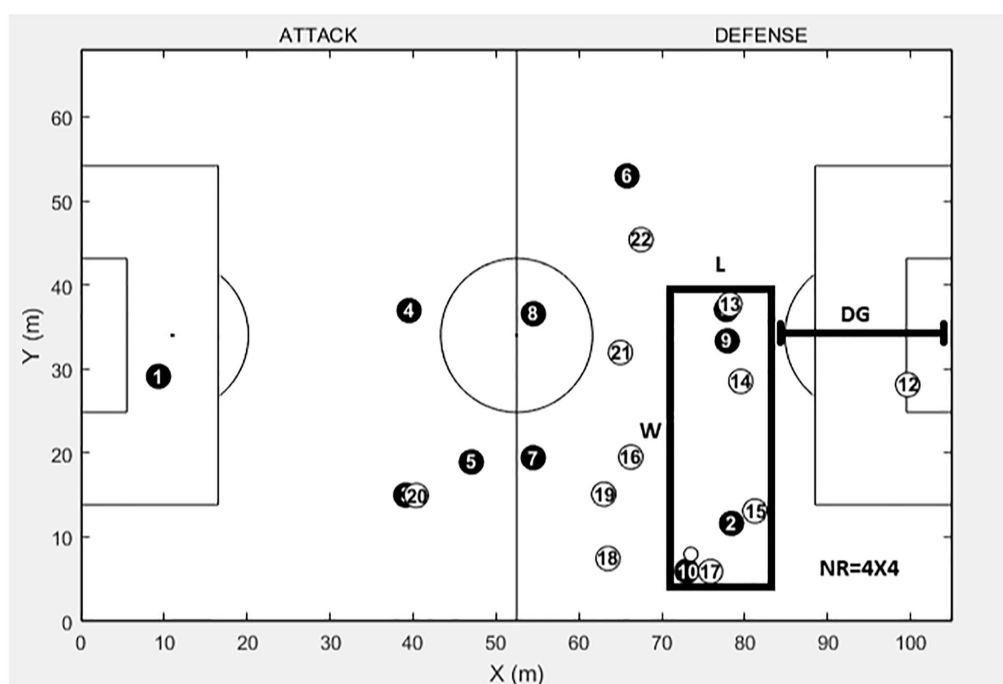


Figure 1. Procedures of data collection: players' position obtained after the tracking procedures, and a representation of the length (L), width (W), distance to goal line (DG) variables, and numerical relationship (NR)

designs were not based on match analyses and were mainly with numerical equality, i.e., the number of attackers was the same as the number of defenders. Furthermore, during training sessions, coaches typically design rectangular areas that may differ from the effective playing space, usually represented by areas with more than one vertex. There is a need for a characterization of the playing space, defined by the values of length and width, the numerical relationship, and the distance of the defenders from goal line during official matches in order to provide insights for designing SGGs based on real match situations. Therefore, the purpose of this study was to analyse the most recurrent characteristics of soccer attacking sequences regarding the effective space available, the numerical relationship, and the distance between the defensive line and the goal.

Material and methods

Participants

The sample consisted of 101 professional Brazilian players from 5 different teams taking part in 4 matches of the 2014 Second Division of São Paulo State League. The matches were recorded in Campinas, São Paulo state, Brazil. The score difference ranged from 1 to 2 goals.

Data collection procedures

The matches were recorded by 4 digital cameras (30 Hz), positioned at the highest points of the stadiums, remaining static; each covered at least one quarter of the pitch. Before the matches, the coordinates of the specific points associated with the pitch coordinate system were obtained. After the games, the videos were transferred to a computer and the DVideo software was used to determine the corresponding projections of these points in the image. The homography parameters of the image-object transformation were calculated on the basis of the proposed direct linear transformation method [20], and the 2D coordinates of the players were reconstructed in relation to the pitch coordinate system. DVideo has an automatic tracking rate of 94% of the processed frames, an average error of 0.3 m for the determination of player position, and an average error of 1.4% for the distance. The trajectories were smoothed by a third-order Butterworth low-pass filter with a cut-off frequency of 0.4 Hz, as previously reported [21].

The variables of the study were quantified frame

by frame and analysed by each attacking sequence, defined as the interval between the first pass after a restart of play (i.e. goal kick, throw-in, free kick) until the ball was out of play. As illustrated in Figure 1, the variables analysed were: (1) the length, (2) the width, (3) the numerical relationship, and (4) distance between the defender line and the goal line. The length was defined as the longitudinal distance between the player with ball possession and the nearest opponent from the goal line. The width was defined as the distance between the 2 more distant players, laterally. The numerical relationship was determined by the number of attacking players (players of the team with ball possession) and by the number of defensive players (players of the team without ball possession) within the area defined in terms of the width and length variables. Therefore, the defensive superiority was considered when the number of defenders was bigger than the number of attackers. Equality was identified when the number of defenders was the same as the number of attackers. In turn, offensive superiority occurred when the number of attackers was bigger than the number of defenders. Thus, if there were 7 attacking players against 6 defenders, for instance, the numerical relationship would be represented by 7×6 . The distance between the defender line and the goal line was defined as the distance between the defensive player closer to the goal line and the goal line.

Statistical analysis

All data are presented as means \pm standard deviations. The chi-square independence test was used to evaluate the difference between the frequencies (in relation to the total number of frames) analysed in all numerical relationships and also in conditions of defensive superiority, equality, and offensive superiority. The level of significance was set at $p < 0.05$. All statistical procedures were performed with the MATLAB software (MathWorks Inc., Natick, MA, USA).

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of São Paulo State University.

Results

All offensive sequences presented the mean values and standard deviations of 24.59 (\pm 13.40) m for

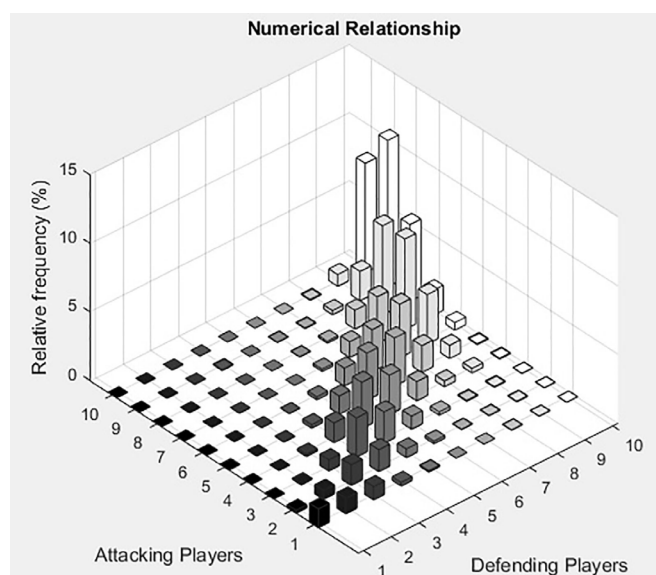


Figure 2. Relative frequency of all numerical relationship combinations among attackers and defenders during all studied matches

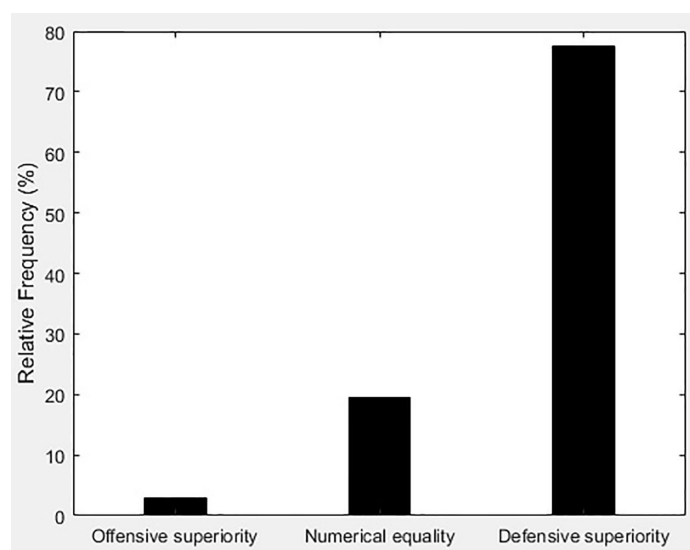


Figure 3. Relative frequency of offensive superiority, numerical equality, and defensive superiority during all studied matches

Table 1. Relative frequency (%) of the numerical relationships among attackers and defenders during the matches

		Defending players									
		1	2	3	4	5	6	7	8	9	10
Attacking players	1	1.38	1.15	0.97	0.26	0.10	0.00	0.01	0.04	0.03	0.02
	2	0.22	0.66	1.52	1.60	0.64	0.19	0.04	0.05	0.05	0.03
	3	0.01	0.08	0.82	2.86	2.27	0.95	0.25	0.08	0.07	0.03
	4	0.00	0.01	0.17	1.43	3.38	2.89	1.40	0.45	0.34	0.06
	5	0.02	0.01	0.04	0.26	1.33	3.45	3.53	1.96	0.96	0.07
	6	0.01	0.00	0.00	0.02	0.22	1.29	3.09	3.92	3.61	0.56
	7	0.01	0.00	0.00	0.00	0.00	0.17	1.16	3.41	6.61	1.82
	8	0.01	0.00	0.00	0.00	0.00	0.03	0.14	1.39	6.52	5.60
	9	0.01	0.01	0.01	0.07	0.01	0.04	0.06	0.30	2.15	10.69
	10	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.07	0.86	7.96

the length, $44.13 (\pm 12.51)$ m for the width, and $29.19 (\pm 11.40)$ m for the distance to goal line. The relative frequency of all numerical relationships between attackers and defenders during the matches are presented in Figure 2 and Table 1. A significant difference was found between the groups ($p < 0.001$), indicating that larger numbers of participating players are more recurrent and that greater numbers of cases are close to numerical equality or little disadvantage.

Significant differences were observed between the relationships of superiority and equality during a match play, showing that defensive superiority is predominant in the game, followed by equality and, finally, offensive superiority ($p < 0.001$) (Figure 3).

The values for length ranged between $1.2 (\pm 1.4)$ and $45.9 (\pm 6.5)$ m (Table 2); width values ranged between

$9.5 (\pm 0.1)$ and $54.0 (\pm 7.0)$ m (Table 3). The bigger the length and the width values, the more players are involved.

Table 4 presents the distance to the goal line during all the matches and the corresponding numerical relationships.

Discussion

This study aimed to analyse the most recurrent features of soccer attacking sequences regarding the effective space available, the numerical relationship, and the distance between the defensive line and the goal, with the rationale to provide coaches with insights to design soccer drills or SSGs during trainings in contexts similar to real match situations. Our

Table 2. Mean (standard deviation) of the length (m) for all numerical relationship combinations among attacking and defending players

	Defending players									
	1	2	3	4	5	6	7	8	9	10
Attacking players										
1	1.2 (1.4)	3.4 (3.3)	14.2 (11.7)	6.5 (5.4)	9.4 (3.5)	15.7 (0.5)	19.3 (1.7)	21.3 (2.2)	23.8 (1.9)	23.1 (2.5)
2	2.6 (2.2)	4.3 (2.9)	8.1 (7.3)	9.0 (5.4)	12.3 (5.1)	13.4 (4.9)	16.8 (4.4)	22.2 (1.6)	22.8 (1.7)	24.5 (1.7)
3	1.8 (1.0)	5.9 (3.7)	8.8 (5.0)	10.6 (6.0)	12.5 (6.1)	14.0 (5.6)	14.3 (6.9)	21.5 (6.3)	22.3 (2.2)	24.9 (1.6)
4	1.0 (0.1)	7.1 (2.9)	10.4 (6.2)	11.4 (6.9)	13.1 (5.7)	15.6 (6.4)	16.9 (5.1)	17.5 (5.7)	20.3 (4.7)	30.1 (1.9)
5	1.4 (0.7)	2.7 (0.4)	7.0 (2.8)	14.0 (8.1)	16.0 (6.8)	17.1 (6.7)	19.2 (6.4)	19.3 (5.7)	20.8 (4.4)	23.0 (2.4)
6	4.1 (0.7)	–	2.5 (0.0)	22.6 (17.8)	17.7 (8.0)	23.1 (8.0)	22.5 (7.2)	22.1 (5.9)	22.3 (5.3)	28.1 (6.2)
7	6.7 (0.8)	–	–	–	–	25.5 (7.9)	26.0 (9.3)	26.1 (7.6)	25.1 (5.6)	27.7 (5.0)
8	9.5 (0.8)	–	–	–	–	33.8 (9.1)	29 (10.2)	31.9 (7.9)	28.8 (6.7)	31.0 (5.2)
9	12.2 (0.8)	13.9 (0.3)	15.5 (0.6)	23.9 (4)	32.3 (0.5)	35.1 (3.2)	42.3 (8.2)	39.5 (6.5)	35.5 (8.3)	35.6 (5.3)
10	–	–	–	–	–	30.0 (0.6)	31.9 (0.5)	41.8 (4.0)	45.9 (6.5)	43.2 (7.1)

Table 3. Mean (standard deviation) of the width (m) for all numerical relationship combinations among attacking and defending players

	Defending players									
	1	2	3	4	5	6	7	8	9	10
Attacking players										
1	13.0 (10.6)	21.0 (10.8)	20.9 (7.8)	30.9 (7.5)	31.3 (3.0)	24.9 (0.3)	25.5 (1.2)	32.6 (6.8)	31.4 (3.5)	29.2 (5.2)
2	25.4 (11.0)	25.0 (9.1)	26.2 (8.2)	32.7 (8.6)	36.8 (8.3)	39.9 (10.4)	32.3 (5.8)	31.8 (5.7)	33.9 (3.0)	32.7 (4.6)
3	25.2 (10.7)	31.4 (6.4)	32.3 (8.9)	34.2 (9.2)	36.3 (8.9)	38.8 (8.2)	38.8 (7.5)	34.6 (8.8)	37.5 (9.1)	34.9 (5.1)
4	16.1 (3.3)	31.4 (8.6)	32.8 (5.5)	37.2 (8.5)	38.4 (8.9)	38.3 (8.5)	41.7 (7.3)	42.3 (5.8)	42.6 (6.2)	37.3 (4.5)
5	14.5 (5.0)	9.5 (0.1)	17.0 (12.6)	38.0 (8.5)	41.9 (8.7)	41.9 (8.3)	43.6 (7.7)	44.4 (7.5)	44.6 (6.8)	43.1 (6.2)
6	20.9 (0.3)	–	28.6 (0.2)	35.0 (9.1)	45.3 (11.0)	44.2 (9.0)	45.0 (7.9)	46.3 (6.9)	46.8 (7.2)	45.9 (7.6)
7	21.6 (0.3)	–	–	–	–	43.8 (6.6)	46.6 (8.3)	46.9 (7.7)	48.7 (6.9)	49.5 (7.2)
8	23.0 (0.5)	–	–	–	–	38.7 (7.1)	41.9 (10.5)	49.0 (9.3)	50.9 (7.0)	52.6 (6.7)
9	24.8 (0.5)	25.8 (0.2)	27.1 (0.6)	32.1 (1.6)	35.6 (0.3)	37.0 (1.2)	39.5 (4.4)	46.0 (8.2)	50.4 (8.3)	54.0 (7.0)
10	–	–	–	–	–	35.5 (0.1)	35.3 (0.2)	42.4 (4.7)	48.4 (8.9)	51.9 (7.4)

Table 4. Mean (standard deviation) of distance between the last defender and the goal line for all numerical relationship combinations among attacking and defending players

	Defending players									
	1	2	3	4	5	6	7	8	9	10
Attacking players										
1	12.4 (9.6)	21.3 (11.9)	14.6 (14.6)	24.3 (14.4)	33.0 (12.1)	31.4 (0.0)	30.0 (1.1)	29.7 (2.1)	28.2 (2.0)	29.1 (2.4)
2	12.1 (14.5)	22.1 (13.1)	20.9 (13.3)	27.2 (12.9)	30.1 (11.3)	33.3 (11.2)	30.0 (8.2)	29.4 (2.3)	27.2 (1.8)	28.2 (1.5)
3	17.8 (11.2)	29.2 (14.2)	23.6 (13.9)	26.0 (12.9)	27.2 (13.1)	26.3 (12.4)	24.7 (12.7)	30.1 (7.0)	28.9 (2.1)	30.1 (1.3)
4	28.0 (15.7)	24.8 (7.4)	28.7 (14.3)	25.4 (12.2)	26.4 (11.7)	27.0 (12.6)	27.8 (11.8)	25.9 (10.3)	27.0 (7.2)	29.0 (2.3)
5	43.6 (4.9)	47.5 (0.3)	42.5 (7.7)	27.9 (13.5)	31.6 (12.8)	28.3 (12.4)	28.5 (11.2)	26.9 (10.1)	27.4 (8.6)	25.8 (3.3)
6	37.7 (0.4)	–	13.6 (0.1)	29.2 (19.7)	30.1 (13.3)	32.6 (13.7)	30.3 (11.7)	28.7 (10.1)	27.0 (9.1)	29.9 (5.5)
7	36.3 (0.5)	–	–	–	–	38.6 (11.2)	30.4 (12.2)	30.4 (10.9)	28.1 (8.4)	29.9 (6.9)
8	34.5 (0.5)	–	–	–	–	48.6 (6.6)	35.3 (13.3)	37.0 (10.4)	30.1 (8.8)	30.5 (6.8)
9	33.0 (0.4)	32.1 (0.1)	31.3 (0.4)	26.5 (2.2)	21.7 (0.4)	24.5 (12.1)	42.8 (12.5)	40.6 (11.1)	33.7 (9.5)	31.7 (6.7)
10	–	–	–	–	–	55.6 (0.1)	55.5 (0.1)	46.7 (7.7)	40.5 (9.2)	35.1 (7.6)

results showed a prevalence of large numbers of players involved in the attacking sequences, such as 10×10 , 9×10 , 8×10 , 8×9 , and 7×9 (Figure 2). However, studies have presented that the most common SSG programs involve fewer players [5, 12]. Although the researchers demonstrated the effectiveness of such

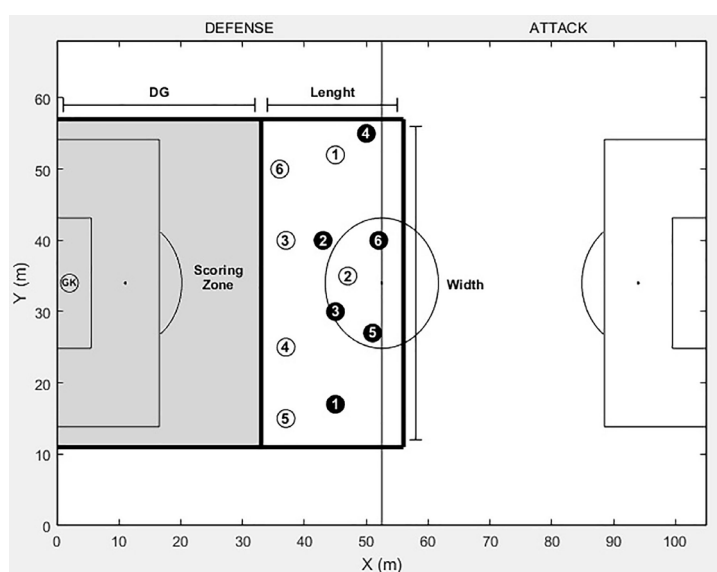
trainings in changing the players' physical and physiological fitness, additional research is necessary to investigate the influence of SSGs with a greater number of players, which are more similar in terms of running, sprinting, loading, and positional roles to an official match [7, 22].

Our findings presented the length and width values considering all the players in front of the one with ball possession. This offers an insight into real situations that players deal with during a match, regarding the available space and number of teammates and opponents for decision-making. Literature studies have presented a great range of effective playing space in different games. For instance, SSGs of 5×5 have been reported in spaces ranging between 28 and 62 m for length, and 14 and 45 m for width [1, 6]. However, for this numerical relationship (5×5), the space configuration found in our results was $16.0 (\pm 6.8)$ m of length and $41.9 (\pm 8.7)$ m of width. Additionally, most studies [1, 5, 12, 14] reported length values greater than the width ones, the opposite of what really happens during a match (Tables 2 and 3). This outcome suggests coaches to review the space and numerical relationship configuration if they expect to better explore game simulations of real situations.

Fradua et al. [14] proposed a design of game space derived from official matches. The researchers computed IPA on the basis of the ball position and used that proportion for all possible SSGs. Although this proposal also simulates real match situations, it assumes that the area per player is always regular during soccer games. On the other hand, with IPA calculated in accordance with the length and width values of Tables 2 and 3, our findings show that when there is a 10×10 numerical relationship among attackers and defenders, IPA equals approximately 112 m^2 . However, in 7×7 situations, for example, IPA decreases to 87 m^2 . This outcome emphasizes the importance of considering a different space configuration for each numerical relationship, once it is expected that decision-making strategies during situations with more players involved in smaller areas are more complex because the players have restricted space and, consequently, restricted time to make decisions and perform actions [6].

The present results provide information that can assist coaches to define specific designs of SSGs, considering that there is an additional space between the last defender and the goal line. Therefore, players must invade the space to perform a shot to goal. Similarly, previous studies reported that the distance between the defender and goal line changed depending on the ball position [13–15]. Additionally, our findings showed that the distance changed depending on the numerical relationship, which is important information to be taken into account in training drills.

Figure 3 presents the difference in the relative frequency of situations with defensive superiority (when



DG – distance to goal line, GK – goalkeeper

Figure 4. Example of a practical recommendation for 6×6 games in accordance with DG, length, and width

the number of defenders is bigger than the number of attackers), equality (when the number of defenders and of attackers is the same), and offensive superiority (when the number of attackers is bigger than the number of defenders). Our results indicated greater values for defensive superiority, considerably different from those observed in literature studies that have focused on evaluating games with numerical equality [1, 5, 12, 14]. On the other hand, Práxedes et al. [9] showed that a training program using numerical superiority was better to improve the decision making in U12 players than a numerical equality program. Therefore, further studies may investigate numerical inferiority/superiority in accordance with the space configuration reported in the present study and the consequences in physical, technical, and tactical demands of the match. Thus, coaches can create and program trainings with different levels of complexity, increasing players' decision-making skills to deal with real match situations.

As for practical recommendations of our paper, coaches may create, for instance, 6×6 SSGs with the spaces presented in the study: about 23 m in length (Table 2) and 44 m in width (Table 3), with the objective of motivating players to invade the space; also, they may use the distance between the defensive line and goal line close to 33 m (Table 4) if the purpose of the game is to score a goal after the invasion (Figure 4).

Conclusions

The study presented the most recurrent characteristics of soccer attacking sequences considering the numerical relationship, the effective space available, and the distance between the defensive line and the goal. We demonstrated that the most recurrent attacking sequences had a large number of players involved. The length, width, and distance between the defender and the goal line are influenced by the numerical relationship and usually width is greater than length. Regarding the numerical relationship between defenders and attacking players, our study identified more situations of defensive superiority, followed by equality contexts. These characteristics can support coaches to design SSGs during trainings in order to improve players' skills to deal with what happens in real situations during a soccer match. The limitations of the study are mainly related to data acquisition. Because of the small sample size, generalization of conclusions drawn could be limited and further studies should incorporate a higher sample of matches. However, we emphasize that the high-cost of real time technologies to collect player position as a function of time, like the Global Positioning System or Local Positioning Measurement, is still a restriction for the great part of researchers and sports staff. Instead, an accurate and low-cost video-based system was used, which, on the other hand, increased the processing time substantially.

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Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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