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Section III – Sports Training

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Analysis of Match Dynamics of Different Soccer Competition Levels Based on The Player Dyads

by

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The purpose of this study was to analyse the dynamics of play based on dyads during soccer matches, according to the competition level, period of the matches, and playing positions. We recorded eight Brazilian soccer matches (four of the national and four of the regional level), using up to six digital cameras (30 Hz). The position information of the 204 players in the eight matches was obtained using an automatic tracking system. The Euclidean distance between the nearest opponents was calculated over time to define the dyads. The interaction between the components of dyads was assessed by the distances between players and was compared among the different positions (defender, full-back, defensive midfielder, midfielder, and forward), match periods (15, 30, 45, 60, 75, and 90 min), and competition levels. Results showed smaller distances for the national level dyads, compared to the regional matches. Greater distances between the players were found in the last 15 minutes of the matches, compared to the other periods. The full-backs were more distant from opposing players compared to players from other playing positions. Thus, coaches should consider the characteristics of each playing position and the greater proximity between opponents' players in top-level competition for the development of tactical proficiency of the players.

Key words: *automatic tracking, dynamical system, interpersonal interaction, sport performance, tactics.*

Introduction

Soccer, similarly to other team sports, presents itself as a dynamic system, where there is a relationship of competition between the teams and the cooperation of the members of the same team (Bar-Yam, 2003; Kalinowski et al., 2019). This modality is characterized as a complex system, in which the organization occurs at several levels. Teams are considered subsystems, which have their own subsystems, for example, defenders, midfielders, and attackers. These groups, in turn, are constituted by other subsystems, which are the players (McGarry et al., 2002). The structures or organization in a soccer match may be analysed in a general way, as well as element-by-element. Moreover, systems with so many elements interacting dynamically must be analysed from a dynamic system perspective (Grehaigne et al., 1997). However, analyses of individual behaviours may represent the behaviour of the group as a whole, and elucidate how players influence and are influenced by the entire dynamic system they belong to (Glazier, 2010).

Registering the position information of players as a function of time during official matches or training sessions allows for the analysis of physical performance of players (Barros et al., 2007), as well as tactical aspects of the sport (Moura et al., 2012, 2013). The individual and collective tactical behaviours during matches can be registered and, by using mathematical tools, quantitative analyses of game may be performed (Yue et al., 2008). The players' behaviour can be analysed through the interaction between two players, labelled as a dyad (Araújo et al., 2014). A dyad can be defined as a pair of

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elements that have something that connects them and these elements are analysed as a unit. This approach has already been used in soccer to evaluate the relationship between teammates (Folgado et al., 2014). Other researchers highlight the relevance of the analysis of interactions between opposing players, in which it is possible to obtain important information regarding the performance of the teams (Araújo et al., 2015; Travassos et al., 2013).

The interaction of dyads constituted by opposing players has been already analysed during training sessions with simulated games (Clemente et al., 2012, 2013; Headrick et al., 2012). The displacements of players were examined in offensive sequences influenced by different instructional constraints, labelled by the authors as situations of risk, neutral, and conservative (Clemente et al., 2012). In the risk situation, the authors simulated that the team was losing during the last minutes of the match, so the attacker should try to score a goal immediately. Conservative instruction was when the attackers' team was winning and thus he should attack whenever he had the opportunity. In the neutral instruction, the attacker was informed that should try to score a goal. Different displacement behaviours were visualized, as well as different duration of attacking sequences in each situation. Another study analysed distances between players and the ball during dribbling attempts in different areas of the pitch (Headrick et al., 2012). Results showed that the distance between the defender and the ball decreased as players approached the goal. Recently, the distance, velocity, and angular amplitude between dyads formed by attackers and defenders were investigated (Clemente et al., 2013). It was verified that the distance between the players decreased, as they got closer to the goal. Furthermore, the difference of the speed and the angular amplitude increased especially when the attacker tried to surpass the defender.

These studies demonstrate the relevance of analysing the interaction between players who compose the dyads to understand players' strategies and organisation during attacking-defending contexts. However, these studies were conducted during training sessions with small-sided games or simulations of specific situations of a match. Thus, these results may not represent what occurs during official matches, once the size of the playing area (Frencken et al., 2013) and the number of players involved (Silva et al., 2016) affect the team interaction patterns. In addition, the absence of other players may alter behaviour during the simulations, not reflecting the real complexity of a match, in which players are considered elements of a dynamic system that are constantly interacting (Grehaigne et al., 1997).

Moreover, in the literature it has been shown that the level of the teams influences the physical (Rampinini et al., 2007), and technical demand of the match (Dellal et al., 2011), and even tactical features of the teams (Folgado et al., 2014). Additionally, previous research has already shown a reduction in players' physical, technical, and tactical performance during the second half of the match compared to the first (Barros et al., 2007; Bradley et al., 2009, 2011; Moura et al., 2013; Rampinini et al., 2009). However, to the best of our knowledge, it is unknown how the technical level of the teams (teams of different levels of competition, for example) affects the interaction of dyads composed of opponent players, or even the behaviour of this variable in different periods of the match. Identifying the level of proximity between the opponent players may provide information regarding the interaction between the teams, such as marking strategies and demands during different levels of competition. In addition, as there is a decrease in players' physical performance from the first to the second half, and considering that the dyad interaction depends on the displacement and velocities of the players, an interesting factor to analyse is whether the level of proximity between the players changes throughout the match.

Thus, the purpose of the present study was to analyse the dynamics of play based on the dyads (distances between the nearest opposing players) during official soccer matches, considering different levels of competition, match periods, and playing positions. Our initial hypotheses were that a) players would present greater proximity in matches of a higher level of competition; b) different positions of game would present different dyads features; and c) the distance between the players of the dyads would increase over time during the matches.

Methods

Data collection

A total of eight official soccer matches were analysed, four from Serie A of the Brazilian national league and four from Serie A2 of the São Paulo regional league. Images of the matches were registered by up to six digital cameras (30 Hz) that were fixed at elevated positions of the stadium. Each camera covered approximately a quarter of the pitch, with an overlapping region between them. The players' positions as a function of time were then obtained using an automatic tracking system.

Participants and automatic tracking method

The automatic tracking system of DVideo software (Barros et al., 2007; Figueroa et al., 2006) was used to obtain the trajectories of 204 professional soccer players (103 players of the national and 101 of the regional competition level), excluding goalkeepers. The two basic automatic procedures of segmentation and tracking generated the positions of players as a function of time throughout the entire matches. DVideo software had an automatic tracking rate of 94% for the processed frames, having the remaining frames solved manually by an experienced operator (Figueroa et al., 2006). This system presented an average error of 0.3 m for determining the player position and an average error of 1.4% for determining the distance covered (Barros et al., 2007; Figueroa et al., 2006). Before the matches, we obtained the coordinates of approximately 36 control points on the field, which were defined relatively to the coordinate system associated with the field. The corresponding projections of these points in the image were determined using DVideo software. The homography variables of the image-object transformation were then calculated using the direct linear transformation method, and the players' two-dimensional coordinates were obtained relatively to the coordinate system of the field. The two-dimensional coordinates of the players' trajectories were then filtered using a third-order Butterworth low-pass filter with a cut-off frequency of 0.4 Hz.

Data analysis

In each instant of time, we identified which team had the ball possession (Moura et al., 2012, 2013). The two-dimensional coordinates of players were used to create an individual surface map, representing the regions of the pitch most visited by the players (Moura et al., 2015). From these surface maps, the position of each player was classified during the match, taking as reference a model (Figure 1) adapted from the classification previously suggested in literature (Di Salvo et al., 2007). Thus, the players were classified as defender (DF, n = 44), full-back (FB, n = 37), defensive midfielder (DM, n = 37), midfielder (MF, n = 41), or forward (FW, n = 45).

Distance between players

At each instant of time, with the players' 2D coordinates (Figure 2A), we calculated the distances of each player in relation to all players of the opponent team (Figure 2B). The calculation was performed having as reference the players of the team without possession of the ball, according to Equation 1.

$$d_{p_{tw}}(i) = \sqrt{\left(x_{P_{tb}(i)} - x_{P_{tw}(i)}\right)^2 + \left(y_{P_{tb}(i)} - y_{P_{tw}(i)}\right)^2}, \quad i = 1, \ldots, n,\ p_{tw} = 1, \ldots, 10,\ p_{tb} = 1, \ldots, 10 \qquad (1)$$

where *i* indicates the instant of time and *n* the total of frames that the players were analysed, *p* represents the player analysed, *tw* is the team without the possession of the ball, and *tb* is the team in possession of the ball.

The values were stored in a matrix and, for each player, at each instant of time, we identified the nearest opponent player (Figure 2C), allowing to define the players who composed the dyads (Figure 2D). The players of the team without possession of the ball were defined as *defending* players, while the players of the team with ball possession were defined as *attacking* players.

Statistical analysis

The Lilliefors test was conducted to assess whether the data were normally distributed. The homogeneity of the variance of the data was examined by the Levene's test. A normal distribution and homogeneity of variance were not found in all situations, thus a Box-Cox transformation was performed to reduce anomalies such as nonadditivity, nonnormality, and heteroscedasticity. A three-way analysis of variance was used to compare the distance between the players according to three factors:

playing position (DF, FB, DM, MF, FW), period of the match (15: 0 - 15 min, 30: 16 - 30 min, 45: 31 - 45 min, 60: 46 - 60 min, 75: 61 - 75 min, 90: 76 - 90 min), and competition level (national and regional). When differences were found in the F-test, the Tukey honestly significant difference test was performed as a post hoc test. A significance level of $p < 0.05$ was used for all statistical analyses. A test was considered relevant if there was statistical difference and the difference of the means was greater than the 0.6 m, i.e., relative to the double of the error for determining the player position. The variables were expressed as the mean and standard error of the mean (SEM).

Results

The values of distance between the players of the dyads according to the playing position, the periods of the matches, and competition levels are presented in Figure 3. Statistically significant differences were found for the interactions between the playing positions and periods of the matches ($F(20,6456488) = 273.36$; $p < 0.01$), playing positions and competition levels ($F(4,6456488) = 5997.79$; $p < 0.01$), and for periods of the matches and competition levels ($F(5,6456488) = 1515.32$; $p < 0.01$). All relevant differences for the interactions can be seen in Figure 3.

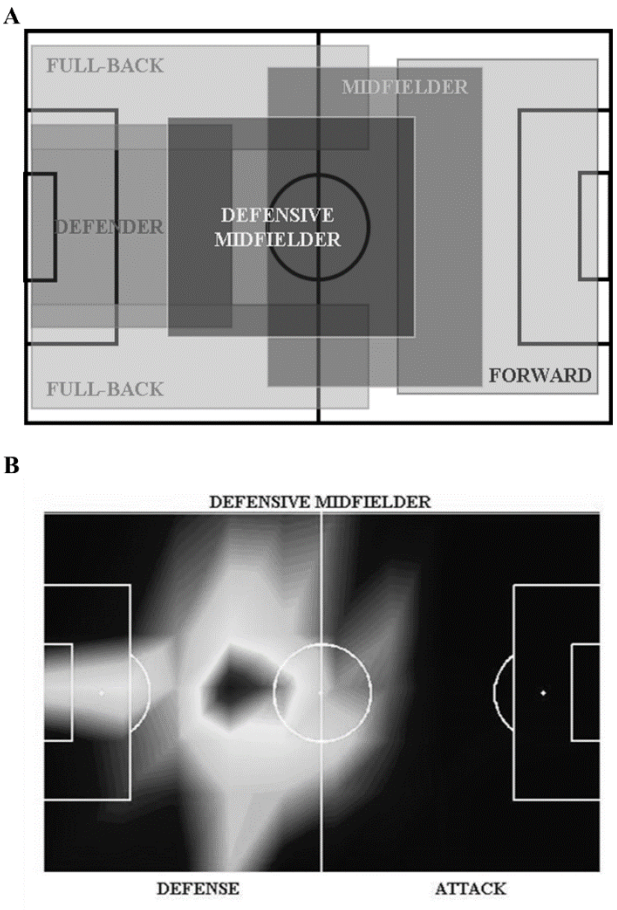

Figure 1

Variables for classification of the playing positions (Figure 1A) and the classification of a defensive midfielder using the surface map (Figure 1B).

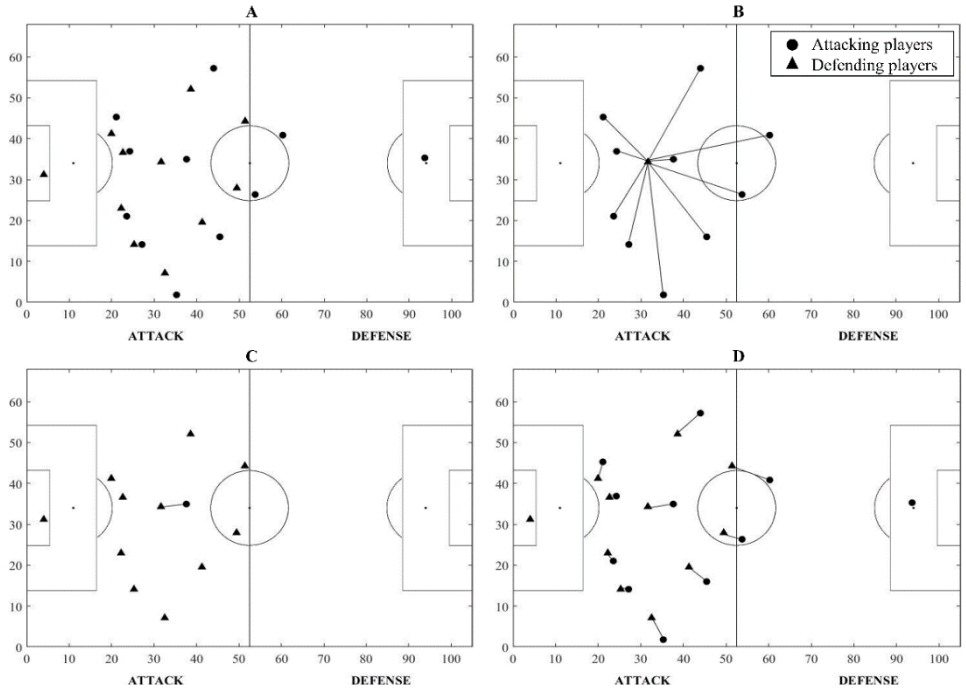

Figure 2

Examples of the 2D coordinates of all players at instant of time (Figure 2A), the distances calculated between a given defending player and all opponents (Figure 2B), the identification of the nearest opponent player (Figure 2C), and definition of the players who composed all the dyads (Figure 2D).

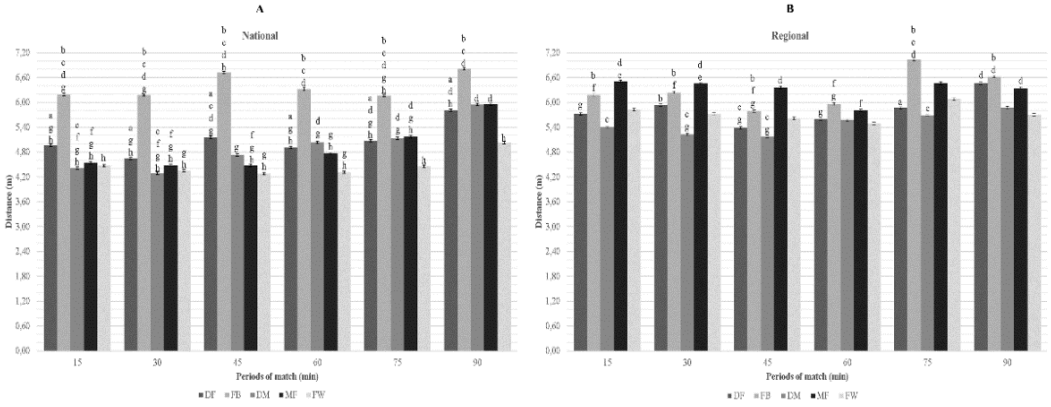

Figure 3

Values (mean and standard error of the mean) of distance between players' components of the dyads according to playing positions, periods of the matches, national (Figure 3A) and regional (Figure 3B) competition levels.
a: relevant difference vs. FB, b: vs. DM, c: vs. MF, d: vs. FW, e: vs. 60 min, f: vs. 75 min, g: vs. 90 min, h: vs. regional.

Table 1

Mean (standard error of the mean) distance between players' components of the dyads according to the playing position, period of the match, and competition level main effects.

Factor	Mean (SEM)
Playing position	
Defender	5.46 (0.0034)
Full-back	6.36 (0.0038) *
Defensive midfielder	5.21 (0.0039)
Midfielder	5.62 (0.0041)
Forward	5.11 (0.0036)
Periods	
15 min	5.43 (0.0041)
30 min	5.35 (0.0041)
45 min	5.39 (0.0041)
60 min	5.37 (0.0041)
75 min	5.73 (0.0041)
90 min	6.04 (0.0041) #
Competition level	
National	5.16 (0.0024) $
Regional	5.94 (0.0024)

SEM: Standard error of the mean;
**: Relevant difference vs. defender, defensive midfielder, midfielder, forward groups;*
 # Relevant difference vs. 15, 30, 45, 60 min groups;
$ Relevant difference vs. Regional group.

The results of the statistical analysis according to the playing position main effect ($F(4,6456488) = 17360.67$; $p < 0.01$) confirm that the value of distance of the FB was greater compared to the other positions. The analysis of main effect related to the periods of the matches ($F(5,6456488) = 4553.19$; $p < 0.01$) demonstrated that the distance in period of 90 min was greater compared to the other periods, except for the 75 min. Regarding the competition level, the main verified effect was a lower value of distance in the national level compared to the regional level ($F(1,6456488)= 52906.49$; $p < 0.01$).

Discussion

The purpose of the present study was to analyse the dynamics of play during Brazilian official soccer matches based on the dyads composed by the nearest opposing players. Specifically, we were interested in characterising

players' interaction from different levels of competition and positions, during periods of the match. The key results showed that the players stayed closer in matches of the national competition level in comparison to the regional level for the most of playing positions and periods of the matches. In comparison among different periods of the matches, we initially hypothesised that an increase of the distance between the players over time would occur. This outcome was confirmed by the results found for the period of 90 min, which showed higher values compared to the other periods. Furthermore, the comparison among the playing positions showed that the FB remained more distant from the opponents than the other positions, during all periods of matches at the national level. However, this result was not found for the regional level players. When the main effect for the playing position was analysed, the superiority of the distance values for the FB compared to the others confirmed our initial hypothesis.

The results of distance between the players of the dyads considering the interaction of the factors (competition levels, periods of the matches, and playing positions) allow to analyse in detail the players' interaction. When the difference between the levels of competition was evaluated, it was verified that, except for the FB, DM, and for the period of 90 min, all the other playing positions and periods of the matches, the national level players covered lower distances (Figure 3). Therefore, players in a national competition match maintained a higher level of proximity compared to players at the regional level. This was an expected result because the national competition was considered as a higher level in this study. Thus, smaller distances between opponents represent a higher requirement of top-level competitions, requiring faster decision making during the matches. This greater requirement was reported previously in a similar way (Mohr et al., 2003), in which it was demonstrated that top-level players covered greater distance in moderate and high intensity running or sprint. Also, the total distance covered and the distance covered at high intensity are greater when teams play against opponents of the higher level of competitiveness (Rampinini et al., 2007). In addition, there is a greater tendency of coordination between teammates when they play against teams at the elite level (Folgado et al., 2014).

The fact that the behaviour of proximity to opponents for the FB was not different between the national and regional levels may suggest that the players of this position have similar characteristics at both levels of competition. However, for the DM, we observed lower values for the national compared to the regional level in the first two periods of the matches. Also, these periods were different from the 60, 75, and 90 min, what may indicate that they were unable to maintain their performance because of the high requirement of national level play. Thus, the DM kept more distant from opponents in the last periods and the distance values were not different at the regional level. The same possible explanation can be applied to the 90 min period, in which all playing positions (except for the DF) did not present differences between the levels of competition.

When particular periods of matches were observed (Figure 3), the 90 min showed higher values of distance between opponents than the other periods for all playing positions at the national level (except for the FW in the 75 min period). This effect over time was expected because players suffer a reduction in performance because of fatigue (Mohr et al., 2003), and suggests that players are unable to maintain the level of proximity to the opposing players. However, a similar outcome was found for the regional level (Figure 3B) for the DF (15, 45, 60 min), FB (45, 60 min), DM (30, 45 min), and possibly the demand at that level of play does not induce relevant differences between the periods of the matches for all playing positions. When we analysed the period main effect (Table 1), players kept more distant from opponents in the 90 min period compared to the other periods (except for 75 min). This result is supported by other studies, which reported a decrease in physical performance in the second compared to the first half, indicating that players covered a smaller distance or performed fewer high-intensity actions (Barros et al., 2007; Bradley et al., 2009; Mohr et al., 2003). In technical demand, a reduction in the number of passes and in the effectiveness of the passes from the first to the second half was also reported (Bradley et al., 2011; Rampinini et al., 2009). In the tactical context, a

previous study demonstrated that the speed of the tactical reorganization of the teams decreased in the second period of the match (Moura et al., 2013). These results presented in the literature are commonly associated to players' physical exhaustion, because of physiological changes that can result in a state of fatigue, such as dehydration and reduced glycogen stores (Mohr et al., 2005; Stolen et al., 2005). Thus, it is possible that fatigue may influence the level of proximity among opponents' players, especially in playing positions associated with a higher defensive responsibility.

Comparing playing positions, it is possible to identify that, for the national level, the FB presented greater distances from the opponent than the others, during all periods of the matches. Additionally, the FW remained closer to their opponents compared to the other positions during the periods of 75 and 90 min. FWs play in an area of the pitch close to the opponents' goal and are directly involved in offensive sequences offering scoring opportunities against the adversary. Therefore, even when the team of the FW had no ball possession, there were opposing players near him, which reduced scoring chances as soon as the FW team regained possession of the ball. Similar results were found for the regional level in the 90 min period: FWs presented lower distances from opponents than the DF, FB, and MF. Furthermore, the DM showed a higher level of proximity to their opponents than the FB (except in the 60 min) and MF (except in the 60 and 90 min). Probably, this behaviour is related to the greater defensive responsibility of the DM compared to the MF and to the fact that this playing position acts most of the time in the central area of the field, having greater interaction with the compared to the FB. In regional competitions, the FB presented greater distances from opponents, compared to the other playing positions, as at the national level, but only during the period of 75 min (Figure 3B and Table 1). Usually, FBs are more distant from opponents because they act predominantly on the sides of the field. This interaction can be clearly visualised by the areas of responsibility on the field by using Voronoi diagrams. A previous study reported that the FB usually presented greater responsibility areas, due to greater distances from the opponent (Kim, 2004).

The contribution of this study was to show that there were differences in the interaction between opposing players at different levels of competition, and that this interaction was influenced by the period of the match and playing positions. Thus, coaches should consider this behaviour of players when planning their training interventions. In top-level competitions, players remain closer to the opponents, probably requiring faster decision making when in possession of the ball and development of the individual strategies of displacement when not in possession of the ball, to prevent offensive strategies of the opponents. In addition, coaches can observe players who do not maintain the proximity level from the opponent during defensive moments and then perform an intervention.

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