Measuring Tactical Behaviour Using Technological Metrics: Case Study of a Football Game

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ABSTRACT

In football, the tactical behaviour of a team is related to the state of ball possession, i.e., the defensive and offensive phases. The aim of this study was to measure the tactical responses of two opposing teams in the moments with and without ball possession, thus trying to identify differences in results arising from tactical metrics such as weighted centroid position, weighted stretch index, surface area and effective area of play. The herein presented results show statistical differences in both teams, either with or without the ball possession, for the -axis centroid (*p-value* ≤ 0.001), -axis centroid (*p-value* ≤ 0.001), stretch index (*p-value* ≤ 0.001), surface area (*p-value* ≤ 0.001) and effective area of play (*p-value* ≤ 0.001). Such results confirm that teams react depending upon ball's possession, respecting the tactical principles of width and length, as well as the unit in the offensive phase with ball possession, and also the concentration and defensive unit in the moments without ball possession.

Key words: Association Football, Ball Possession, Performance Analysis, Soccer, Tactical Metrics

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INTRODUCTION

Team sports are complex systems [1] that require specific strategies of observation to improve the intervention quality of coaches and sports analysts [2]. Such observations are commonly designated as match analysis [3], thus including a set of analysis procedures (e.g., notational, kinematical and tactical analysis). Nevertheless, to analyze the collective performance of teams, it is essential to further understand and determine the relevant parameters to achieve the main goals of observation [4]. The use of specific parameters or performance indicators may give important information to sports analysts, thus improving the interventions quality [5]. These performance indicators are a selection or combination of action variables that aim in defining some aspects of the performance in a given sport, considering its properties and specificities. These indicators allow a better understanding about sports and allow improvement of coaches' intervention [6]. Therefore, the effective evaluation of these indicators requires knowledge about the contextual factors that can potentially affect the performance [7]. The reality of sports performance may be a strongly constraint to correctly understand a specific team. Variables such as match status (i.e., winning, losing or drawing), venue (i.e., playing at home or away) and specific tactical and strategic principles of the team [8] may influence the collective behaviour, and result in changes that may be identified by the performance indicators.

One of the most popular performance indicators in football is the ball possession [8-11]. Some studies found a relationship between the ability to retain the possession of the ball for prolonged periods of time and the competition success [12]. However, the ball possession in each match varies depending on the team under analysis [13] and their tactical and strategic properties. Ball possession strategies are influenced by match variables and teams' playing styles, either independently or interactively [13-14]. The importance of these factors is reflected in changes in a team's strategy as a response to match situations through tactical behaviours [14].

Considering the natural rapport of strength [15] in collective sports, it is imperative to distinguish two terms that, although often used synonymously, have different meanings. Gréhaigne and Godbout [16] described the strategy as a set of elements previously discussed for the organization of the own team. In fact, the strategy relates to the general order, i.e., players positioning on the field as well as the occupied areas and specific missions [17]. Given the tactic concept, Gréhaigne and Godbout [16] described it as a timely adaptation to new game configurations, depending on the movement of the ball as well as the actions of the opponents. In other words, the tactic concept is related to the positioning of players in response to the opponent in a given match moment, dynamically adapting to the playing conditions [15].

Both match status and ball possession influence the strategy and tactical behaviour of team players. Furthermore, the specific properties of teams influence the time expended in either defensive or offensive phase, in which the ball possession is strongly related to the team's strategy and subsequent tactical responses. Inversely, in the defensive phase (i.e., without ball possession) the position of the ball and the opponents' behaviour may constrain the collective behaviour of the team, thus resulting in tactical changes. These tactical adaptations depend on the quality of the collective action and the team's strategy. Nevertheless, some tactical principles are commonly adopted by teams in order to improve the collective performance. The most pertinent tactical principles in offensive phase are the width and length (where players try to extend their movements and use the effective play-space) and the offensive unit (i.e., movement of the last line of defenders towards the offensive midfield, in order to support offensive actions of the teammates) [18-19]. On the other hand, the defensive tactical principles are the opposite of the offensive principles previously articulated, focusing on the concentration (position of off-ball defenders to occupy vital spaces and protect the scoring area) and the defensive unit (positioning of off-ball defenders to reduce the effective play-space of opponents) [18].

These tactical principles may be analysed through metrics that allows a better understanding about the collective behaviour of a team. For instance, the centroid position of players [20-22] may have the potential to compute the in-phase relation among the two opposing teams in longitudinal and lateral directions and also give tactical information about the strong point of the team and how its centroid position oscillates in relation to the state with or without ball possession. It is expected that, with ball possession, the team's centroid gets closer to the scoring zone and farther from it when the team does not have the ball possession.

Another tactical metric recently developed is the stretch index [20] that allows retrieving information about the dispersion of a team in relation to its centroid. This metric allows a better understanding about the tactical principles of the defensive and offensive unit [18]; i.e., all team players act in function of the ball position and the state of their teammates, thus ensuring an optimal proximity between them. According to the principles of width and length (in offensive phase) and concentration (in defensive phase), the stretch index can give some information about the position of players in relation to the state of play. It is expected that the stretch index decreases in the defensive phase (i.e., reducing the space between teammates according to the concentration principle) and increases in the offensive phase (i.e., exploring the width and length of the field, trying to improve the opportunity to score).

As the stretch index only informs about players' dispersion, the surface area [21-22] appeared as a tactical metric that allows a perspective about the potential surface of team's playing area. However, teams' surface area may not give the necessary information about the efficacy of the real effective surface of the team, since opponents' positions are not considered. Therefore, this study proposes a new tactical metric, aiming to measure the team's effective area of play, based on the effective triangles of each team [23], thus complementing the information inherent to the traditional surface area. The number of effective triangles of each team may also characterize the efficiency of the tactical organization. For instance, the effective area of a team may be used to evaluate both defensive and offensive phases.

These tactical metrics previously presented may give vital information for coaches, hence allow a better understanding about the team under analysis. Nevertheless, the tactical behaviour of a team is necessarily different between different ball possession moments. Some studies presented a rigorous work analysing the ball possession through notational analysis [8-11, 14, 24]. Nevertheless, the traditional quantitative analysis (i.e., notational analysis) may not be suitable to establish the whole characteristics of a tactical behaviour. Therefore, the notational analysis should be complemented considering the tactical behaviour of teams and how teams collectively act. The tactical metrics may allow overcoming the limitations inherent to the notational analysis to be overcome [25]. Therefore, this work aims at improving the understanding about the tactical response of teams based on the ball possession state, adding a new kind of information to the studies previously presented regarding notational analysis [8-11, 14, 24].

As previously articulated, the tactical principles and responses of teams are different in both defensive and offensive phases, i.e., without and with ball possession. Considering the ball possession as a fundamental constraint to the collective behaviour of football teams, the aim of this paper is to analyse teams' behaviour using four tactical metrics (i.e., team's centroid, stretch index, surface area and effective area of play). These tactical metrics allow quantitative information about the central position of the team, the dispersion of players according to the team's centroid and how players collectively act with and without ball possession to ensure an efficient formation of the play area. The main hypothesis of this study is to observe significant differences between the tactical metrics in the different moments (i.e., with or without ball possession). More specifically, it is expected that, without ball possession, the centroid position approaches the defensive area, the stretch index decreases and both surface area and effective play area also decreases, thus ensuring the tactical principles of concentration and defensive unit. Conversely, it is expected that with ball possession, the team's centroid gets closer to the opponent's half field, the stretch index increases and both surface area and effective area of play also increase, thus ensuring the tactical principles of width, length and offensive unit [18].

METHOD

SAMPLE

The official football match of the under-13 district final of Portugal was analysed. The match occurred in the specific situation of a 7-a-side game, according to the normative rule of *Federação Portuguesa de Futebol*[1].

PROCEDURES

The analysed match was the district final of under-13 football. Teams' actions were captured using a digital camera (*GoPro Hero* with 1280 × 960 resolution), with capacity to process images at 30 Hz (i.e., 30 frames per second). The camera was placed in an elevated position above the ground in order to capture the whole field. After capturing the football match, the physical space was calibrated using direct linear transformation (*DLT*), which transforms elements' position (i.e., players and ball) in pixels to the metric space [26]. After calibration, the tracking of players was accomplished, thus resulting in the Cartesian positioning of players and the ball over time. The whole process inherent to this approach, such as the detection and identification of players' trajectories, the space transformation and the computation of metrics, was handled using the high-level calculation tool *MatLab*.

TACTICAL METRICS

Online tactical metrics may give to the coach relevant information about how teams behave over time throughout the match. In fact, such metrics can be used as an important tool to improve the coach's opportunities to make changes on the team's tactic, easily detecting the strong or weak aspects of its performance during the match.

Weighted Centroid

For the football game, the centroid can be calculated through the geometric mean position $(\bar{x}, \bar{y})$ of all players (x_n, y_n) for each team. According to Frencken et al. [22], the centroid of both teams can provide three measures: *i*) the *x*-distance (*m*) representing forward-backward displacement (i.e., length of the field); *ii*) the *y*-distance (*m*) representing lateral displacement (i.e., width of the field); and *iii*) the radial distance (*m*), comprising both forward-backward and lateral displacements. These measures are obtained based on the centroid position relative to the origin, i.e., (0, 0), defined at the centre of the field, as:

$$\begin{bmatrix} \bar{x} \\ \bar{y} \end{bmatrix} = \frac{1}{\sum_{i=1}^{N} w_i} \begin{bmatrix} \sum_{i=1}^{11} w_i x_i \\ \sum_{i=1}^{11} w_i y_i \end{bmatrix}. \quad (1)$$

[1] http://www.fpf.pt/portal/page/portal/PORTAL_FUTEBOL/DOCS/REGULAMENTOS/leis_fut_7.pdf

wherein the position of the i^{th} player is defined as (x_i, y_i). Previous studies [20-22] do not consider the positions of the goalkeeper and the ball. Nevertheless, the goalkeeper should be considered due to its preponderance in the defensive phase. Moreover, considering the ball location allows providing weights for each player's influence, in which the higher weight is assigned to the player closer to the ball and the lower weight is assigned to the player farther from it. In other words, the relevance of each player to the team's centroid; i.e., w_i weight, is based on the Euclidean distance from each player to the ball as:

$$w_i = 1 - \frac{\sqrt{(x_i - x_b)^2 + (y_i - y_b)^2}}{d_{max}}, \tag{2}$$

where(x_b, y_b) corresponds to the position of the ball and d_{max} is the Euclidean distance of the farthest player to the ball at each iteration.

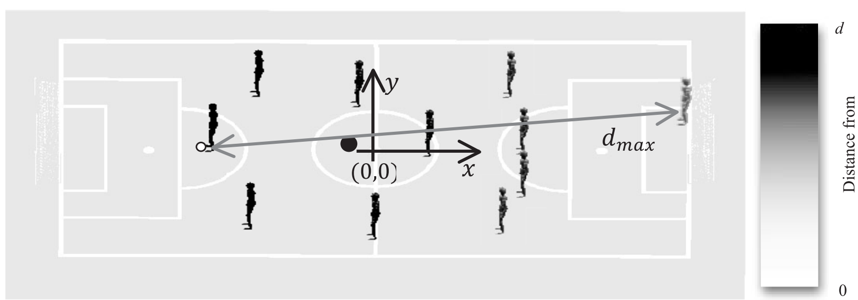

Figure 1. Spatial Referential of the Field

Weighted Stretch Index

The stretch index measures the space expansion or contraction of the team on the longitudinal and lateral directions [20]. Similar to the team's centroid, a weighted team's stretch index metric may be calculated as:

$$s_{ind} = \frac{\sum_{i=1}^{N} w_i d_i}{\sum_{i=1}^{N} w_i}, \tag{3}$$

where d_i is the Euclidean distance between player i and the team's centroid:

$$d_i = \sqrt{(x_i - \bar{x})^2 + (y_i - \bar{y})^2}. \tag{4}$$

Within this context, the stretch index can be obtained by computing the mean of the distances between each player and the centroid of the team. Hence, this metric represents the mean deviation of each player on a team from its centroid.

Team's Surface Area Metric: Effective Area and Triangles

In order to create a polygon on the planar dimension, at least three points are necessary (i.e., triangle). Therefore, three players need to be considered to build triangles as the combinations of players, in which is the total number of players within a team. On the football case, a maximum of eleven players for each team may be in the field at the same time. Consequently, the combination of three players out of eleven players, results in a total of 165 triangles that may be cumulatively formed.

However, it is important to further understand how teams behave and find the real effective area of each team over time. Hence, it may be important to contemplate the effective area of a team; i.e., the real area that a team covers without intercepting the effective area of the opposing team. In fact, the effective area needs to consider the space that a team can efficiently cover. Therefore, the tactical football can be geometrically analysed to further understand how teams behave over time.

Lucchesi [23] indicates that the geometric figures that allow the most successful play along the field are triangles and that the ability of the team to "draw up" such triangles on the field allows a good offensive to develop. In the defensive organization, triangles towards the ball, known as defensive triangles, are always being formed in an attempt to create a "defensive shadow"; i.e., the space through which the opponent cannot pass or dibble due to the triangular-shaped positioning of players [27].

Therefore, as the number of formed triangles within a team increases, the less effective space is left for the opposing team. For instance, Trapattoni [28] claims that when players are pressed and cannot turn around and dribble, the ball must travel along triangles until a solution is found; i.e., the offensive triangles are annulled by the defensive triangles.

After generating all triangles of each team, the next step is to consider all triangles of each team without interception. Through this condition, it is possible to calculate the area of each team without interception. However, in the presence of interceptions between opposing triangles, and based on the supposition that effective defensive triangles can overlap the offensive triangles [28], the effective area to be considered is the one of the defensive triangles (Figure 2a), thus reducing the effective area of the offensive team.

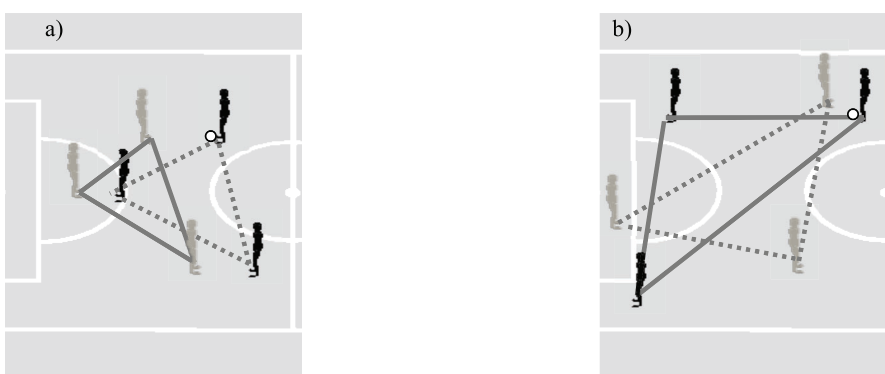

Figure 2. Example of Triangles Interception

Nevertheless, Dooley and Titz [27] show that, in order to form effective defensive triangles, it is necessary to have an approximate distance of 12 meters between each vertex (i.e., defensive players): i.e., a defensive triangle with a maximum perimeter of 36 meters. Hence, if a defensive triangle has a perimeter superior to 36 meters (Figure 2b), it will be overlapped by the offensive triangles since there are no guarantees that the defensive players will be able to intercept the ball. After considering the triangles without interception, it is necessary to consider all triangles of the team that does not have the ball possession (i.e., defensive team) with perimeters inferior to 36 meters. Therefore, the algorithm considers all the defensive triangles that have this condition, overlapping the interceptive offensive triangles.

Finally, all offensive triangles that are not intercepted by the defensive triangles with perimeter inferior to 36 meters are considered. Consequently, the algorithm calculates all triangles, thus calculating the respective effective areas of both teams at every instant (Algorithm 1).

Algorithm 1. Effective Area - Offensive triangles of team δ that are not intersected by the defensive triangles of the opposing team ζ.

If $ball\_possession(\delta) = 1$ // condition is verified when team δ has the possession of the ball
For $i = 1 : \tau^{\delta}$
  $\Gamma = \Delta_i^{\delta} \cap \left(P^{\delta} \cup P^{\zeta}\right)$, $where\ \Gamma = (\gamma_1, \ \cdots, \ \gamma_\alpha)\ and\ \alpha \leq 6$ // analyze intersections between offensive triangles and the effective area of both teams
  $A_{Pol} = \frac{1}{2}\sum_{i=1}^{\alpha-1}\left(\gamma_{1,i}\gamma_{2,i+1} - \gamma_{1,i+1}\gamma_{2,i}\right)\ with\ \alpha \leq\ 6$ // calculate the area of the intersection
  If $A_{Pol} = 0$ // condition is verified when there is intersection between the defensive triangle from team δ and the surface area of team ζ and the perimeter of the defensive triangle is smaller than ρ_{ε}
    $A_{Pol} = \frac{1}{2}\sum_{i=1}^{3}(x_i y_{i+1} - x_{i+1} y_i)$ // calculate the area of the triangle
    $A^{\delta} = A^{\delta} + A_{Pol}$ // cumulative effective area of team δ
    $\varepsilon^{\delta} = \varepsilon^{\delta} + 1$ // counter of the effective triangles of team δ
    $P^{\delta} = P^{\delta} \cup \Delta_i^{\delta}$ // build the polygon of the effective area of team δ by accumulatively uniting its effective triangles

Through this tactical metric; i.e., the effective team's surface area, a coach may analyse if the team, in the defensive phase, acts as a defensive "block"; i.e., the union of the defensive triangles form a defensive polygon that constrains the opponents to lose the ball.

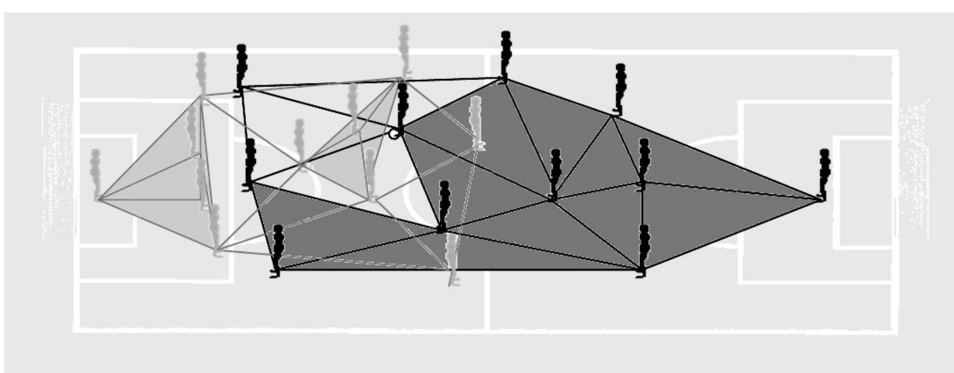

Figure 3. Example of Effective Area with Defensive and Offensive Effective Triangles

Also, over time, the coach or the assistant may analyse if the midfielders' triangles are large enough to allow offensive triangle moving forward without effective opposition. Therefore, the effective area can give important information to the coach about how teams behave and where mistakes or weakness in relation to the opponent may emerge from a specific tactical definition.

STATISTICAL PROCEDURES

The one-way ANOVA was used to analyse the statistically significant differences between teams with and without ball possession. The normality assumption of one-way ANOVA in the two conditions (i.e., with or without ball possession) was assessed using the correction of the Kolmogorov-Smirnov test by Lilliefors. Although the distributions are not normal in the dependent variable, since $n > 30$ and using the Central Limit Theorem [29-30], the assumption of normality was made [31]. The analysis of homogeneity was carried out using the Levene test. It was found that there is no uniformity of practice under the previously mentioned conditions. However, despite the lack of homogeneity, the F test (ANOVA) is robust to homogeneity violations when the number of observations in each group is equal or approximately equal [32-34], which is our case. Also, the violation of the assumption of normality does not radically change the F value [32]. The classification of the effect size (i.e., measure of the proportion of the total variation in the dependent variable explained by the independent variable) was done according to Maroco [29] and Pallant [35]. This analysis was performed using the IBM SPSS program (version 19) for a significance level of 5%.

RESULTS

Results are individually presented for each team and afterwards analysed as a whole. This kind of analysis allows a better understanding about the individual processes of each team. The analysis of both teams may allow asserting if the behaviour of teams is similar according to tactical principles of the football game.

Table 1. Average Results of the Tactical Metrics by Each Team

Team	Ball Possession [BP]	Weighted Centroid *x*-axis [m]	Weighted Centroid *y*-axis [m]	Weighted Stretch Index [m]	Surface Area [m^2]	Effective Area of Play [m^2]
Team A	With BP	-0.63 ± 15.93**	0.26 ± 10.11**	8.19 ± 2.27	3783.65 ± 1489.63*	3511.82 ± 930.91**
	Without BP	-3.39 ± 13.92**	-2.06 ± 9.48**	8.29 ± 2.22	3551.41 ± 1571.74*	1023.63 ± 1458.40**
Team B	With BP	1.79 ± 14.71**	-2.58 ± 8.96**	9.01 ± 2.42**	4170.17 ± 1818.05**	3943.03 ± 1836.41**
	Without BP	4.27 ± 15.53**	-0.22 ± 8.81**	8.36 ± 2.68**	3589.61 ± 1766.91**	1457.72 ± 1261.45**

*p-value > 0.05
**p-value ≥ 0.01

The results of the weighted centroid position in the x-axis showed statistical differences with small effect between the moments with and without ball possession in team A ($F_{(1; 1506)} = 11.786$; $p\text{-}value = 0.001$; $\eta^2 = 0.008$; $Power = 0.929$) and team B ($F_{(1; 1506)} = 9.427$; $p\text{-}value \leq 0.001$; = 0.006; $Power = 0.866$). In both cases, results suggested that without ball possession teams move closer to their defensive zone (*cf.*, Figure 4). In team A, the mean position with ball possession is -0.63 m and -3.39 m without ball possession; i.e., the collective position of the team decreases, thus approaching the centroid position to their goal when without the ball possession. The same tactical behaviour happens with team B showing a mean weighted centroid position of 1.79 m with ball possession and 4.27 m without ball possession.

Considering the results of the y-axis centroid, it is possible to observe statistical differences between the moments with and without ball possession in both teams. In team A, the y-axis weighted centroid average is 0.26 m with ball possession and -2.06 m without ball

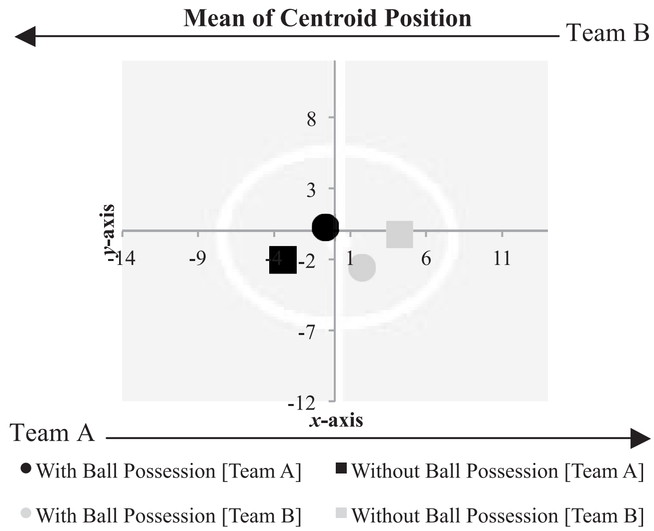

Figure 4. Average of the Centroid Positions of the Two Teams (x-axis: length of the field; y-axis: width of the field)

possession, being statistically different with small effect ($F_{(1;\,1506)} = 19.698$; *p-value* ≤ 0.001; $\eta^2 = 0.013$; *Power* = 0.993). Similar results are found in team B where the mean y-axis weighted centroid is -2.58 m with ball possession and -0.22 m without it, resulting in statistical differences with moderate effect ($F_{(1;\,1506)} = 25.110$; *p-value* ≤ 0.001; $\eta^2 = 0.016$; *Power* = 0.999).

About the weighted stretch index results (*cf*. Figure 5), it is possible to confirm statistical differences with small effect between the moments with and without ball possession in team B ($F_{(1;\,1506)} = 22.777$; *p-value* ≤ 0.001; $\eta^2 = 0.015$; *Power* = 0.998). In the case of team A, the results are not statistically different ($F_{(1;\,1506)} = 0.595$; *p-value* = 0.441; $\eta^2 = 0.001$; *Power* = 0.120).

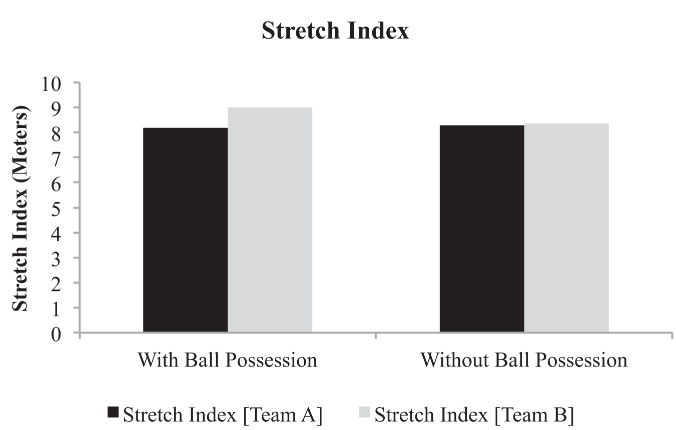

Figure 5. Average of Stretch Index of the Two Teams

The surface area of both teams with and without ball possession are statistical different. In the case of team A, the average surface area with ball possession is 3783.65 m^2 and 3551.41 m^2 without ball possession. These differences are statistical significant with small effect ($F_{(1; 1506)} = 8.308$; *p-value* = 0.004; $\eta^2 = 0.005$; *Power* = 0.821). Similar results are found for team B where the surface area is 4170.17 m^2 with ball possession and 3589.61 m^2 without it. These differences are statistical significant with small effect ($F_{(1; 1506)} = 37.659$; *p-value* ≤ 0.001; $h^2 = 0.024$; *Power* = 1.000).

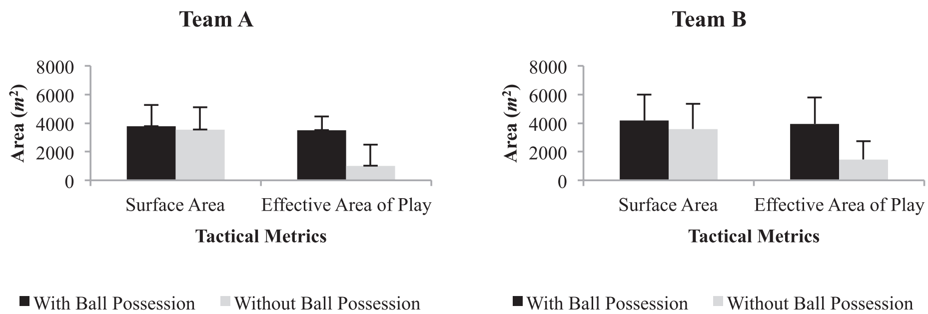

Figure 6. Average Surface Area and Effective Area of Play for Both Teams

Similar to the results of the surface area, it is possible to analyze that the effective area of play of both teams are different regarding the ball possession. In the case of team A, the average of the effective area of play with ball possession is 3511.82 m^2 and 1023.63 m^2 without ball possession. These differences are statistical different with large effect between them ($F_{(1; 1506)} = 1343.893$; *p-value* ≤ 0.001; $\eta^2 = 0.472$; *Power* = 1.000). Similar results are found in the case of team B, where the mean with ball possession is 3.943 m^2 and 1457.72 m^2 without it. The variance analysis shows statistical differences with large effect ($F_{(1; 1506)} = 968.500$; *p-value* ≤ 0.001; $\eta^2 = 0.391$; *Power* = 1.000).

DISCUSSION

Understanding the differences between the playing patterns of teams is crucial for match analysis [6, 13]. For many coaches and sports' professionals, the information obtained from match analysis forms not only the basis for weekly training programs, but also acts as a primary source for the scheduling of season plans [3]. Therefore, the aim of match analysis is to identify the strengths of teams, so they can be further developed, and the weaknesses, which suggest areas for improvement [14].

The football game is a complex system that needs to be understood in its integral dynamic. For coaches' intervention, the strategic and tactical characteristics of their team and the opposing teams constitute an imperative factor that determines the quality of the intervention. Therefore, many coaches believe that the personal playing style of each team ("direct play" or "indirect play – possession play") is an important factor in enhancing the team performance [8]. Nevertheless, the personal playing style can be constrained by many factors such as the quality of the opponent team, the match status or the time with ball possession [15]. Hence, the present work aimed to analyse the tactical responses of two teams at two moments: with and without ball possession. With such analysis, it was possible to observe the potential differences in the teams' collective behaviour.

The ball possession is constrained by the match status or the opposite team. Nevertheless, different teams appear to follow distinct strategies that reflect the individual style of coaching, the players' characteristics, the team's formation or also the team's culture or particular philosophy [36]. The collective behaviour of teams in reaction to the state of ball possession may be substantially different during the match depending on the ball possession. Therefore, the tactical behaviour will necessarily be different depending on the state of ball possession.

The x-axis weighted centroid position allows an understanding of the team's collective behaviour over the game in terms of ball possession and the lack of it. Thus, it was possible to analyse that the collective position is statistically different while with the ball possession, where players try to move forward in the field and aim to reach the opponent's score zone. In the present study, it was possible to analyse that the average y-axis weighted centroid position in defensive and offensive phase is allocated in the defensive half of the field. Tenga et al. [37] showed that 51.6% of the starting zone of the offensive process occurs in the defensive half and 45.5% in the middle half. Through the results, it was possible to conclude that the half, which generates more goals, is the middle half followed by the defensive half. The zone that scores fewer goals is the offensive half.

Nevertheless, a strong imbalance of the collective behaviour between the offensive and the defensive phase can give an opportunity for the opponent team to score. Although statistically different, the eta squared reveals a small effect size. In fact, a higher level in football could be harmful for the team. Therefore, principles as offensive and defensive unit [18] ensure that the proximity between teammates in any match phase would allow for a quick action over the ball and opponents. Therefore, the ability of the team to secure a unit of their players during the entire match can contribute for the improvement of the quality of their tactical intervention [19]. Nevertheless, it is not only in the x-axis weighted centroid position that the statistical differences are observed. The y-axis weighted centroid position also showed statistical differences between the states of with and without ball possession. However, those results cannot be related only to the intrinsic collective behaviour of the team. In previous studies [20], it was possible to observe a strong couple between teams' centroid. Thus, a similar relation can be observed in the present study as well. In fact, both teams, on average attack on their right side and, respectively, the defensive phase happens on their left side. By considering the previous studies [20], it is possible to confirm that the collective behaviour in the centroid' metrics is developed by both intrinsic (e.g., tactical and strategic principles) and extrinsic (e.g., opponent play) factors.

Although weighted centroid position measures the average position of the team [21-22], a complementary metric is important to understand how connected the teammates are in respect to the game, and how related the players are to the team's centroid. Therefore, the weighted stretch index can measure players' dispersion in relation to the weighted centroid position [20]. In offensive phase, the level of the weighted stretch index should be higher when compared to the defensive phase, according to the principles of width and length (in offensive phase) and concentration (in defensive phase) [18-19]. According to the present study, those principles are more evident in team B. Without ball possession, the weighted stretch index is statistically lower in comparison to the offensive phase. In the defensive phase (i.e., without ball possession) players arrange their positions around the centroid and try to reduce the likelihood of the opponent team to enter the scoring zone. Respectively, in the offensive phase (i.e., with ball possession) the team explores the width and length of the field and tries to unbalance the focus and unity of the opponent team. In the case of team A, the similar average results of the stretch index between the states of with and without ball possession may be related to the specific strategy of the team. For example, in the defensive phase, the team can choose to maintain one or two players in the offensive zone, thus reducing the effective number of players participating in the defensive phase. This kind of strategic option is applied when the team has its quality players in defensive phase. This makes it possible to keep the opponent's defensive players in their defensive zone, which ensures that none of the attacker team's players would retreat to the defensive zone.

Based on the aforementioned results, the weighted stretch index can be an important referential to understanding the dispersion level of a team's players in relation to the centroid. However, the weighted stretch index in itself does not allow for an appreciation of the quality of the collective behaviour and the different ways to play. Therefore, the surface area [21-22] happens to be an alternative to understanding the possible ways to play. Nevertheless, the surface area [22] cannot predict the real efficiency of the team. In fact, if one team presents a higher surface area it may suggest that the opponents would have to explore the middle and the danger zones. Therefore, the collective efficacy may only be considered if the team is able to form real offensive and defensive triangulations. Considering that the game is a sum of offensive and defensive triangulations [23] formed by each team, the effective play area, which was developed in this work, can allow for a better understanding of the tactical and strategic behaviour of the team and, consequently, their collective efficiency. Thus, the effective area of play may be a fundamental metric for analyzing the quality of the tactical behaviour of the team.

In the present study, it is possible to observe that the state of the team in relation to the ball possession determines the quality of the tactical behaviour and the different ways to play. According to the concentration and unit tactical principles in defensive phase, teams are expected to reduce the effective area they cover. Respectively, it is expected that in the offensive phase (i.e., with ball possession) higher levels of effective play area are covered, due to the tactical principle of width and length. Those results were observed in both teams, where the variance between the effective area of play, with and without ball possession, was statistically different with large effect. Therefore, this metric allows for an understanding of the proximity of players and if they can collectively perform an effective opposition that would create a defensive unit with a tactical principle which is essential for the quality of the opposition.

In addition, the present methods, such as tactical metrics, may enable the overcoming of the limitation inherent to the notational analysis [25]. Therefore, the notational or kinematical analyses need to be complemented with new methods in order for the team's tactical dynamics to be understood [4]. This kind of information is vital to improve the quality of the game, training and intervention of the coach, thus improving the collective performance of teams or players [38].

PRACTICAL CONSIDERATIONS

The proposed metrics pave the way for new prospects regarding football analysis, being easily adapted to automatic tracking systems. These metrics aim to improve the knowledge regarding the tactical behaviour measuring the accomplishment of playing principles [19]. It is not our aim to replace notational analysis but rather to complement it and improve the retrieved information for coaches and analysts. The relevance of such methods should be understood by considering the playing principles, and not interpreted without considering the football dynamics.

For instance, the stretch index and surface area are related to the principles of defensive concentration and offensive width and length. Both metrics analyse the expansion-contraction relationship in function of ball possession, thus measuring the accomplishment of these playing principles. Therefore, coaches or analysts should interpret the results by considering their own principles of the game. As an example, if they want a higher or lower concentration without ball possession, it is possible to create a warning system with the stretch index and surface area as inputs (e.g., by means of fuzzy decision-making systems), to alert them about higher levels of expansion during the defensive phase.

Likewise, the effective area of play allows understanding the principles of defensive and offensive coverage. Usually, coaches define an optimal distance between players in the defensive triangulations. Hence, the effective area of play allows selecting an "ideal" distance, or range of distances, and verify the effectiveness of such triangulations at each instant.

At the same time, these metrics may reveal the weaknesses and strengths within opposing teams. For instance, the effective area of play allows detection of the regions where the opponent team allocates more effective triangulations.

To depict the metrics potentialities, let us illustrate some practical cases based on a real play situation (see Figure 7 and Figure 8). The graphical representation has some features that should to be considered. The teams' centroid is represented by the centre of the circumferences. The size (i.e., area) of this same circle proportionally varies based on the teams' stretch index. Team A players are represented by blue filled circles and Team B players by red filled circles. The ball is represented by a black filled circle. The effective areas of Team A and B are represented by the blue and red regions, respectively.

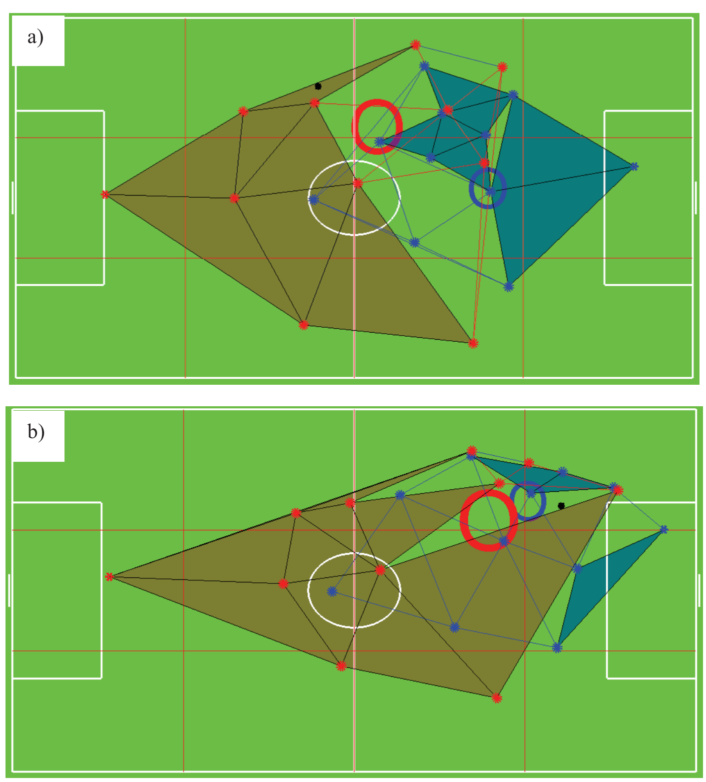

Figure 7. Team A (Blue) Without Ball Possession

In Figure 7, team A (blue) does not have the ball possession but their tactical behaviour is different in each situation presented in Figure 7a and Figure 7b. Despite not having the ball possession, team A is able to generate seven effective triangles in Figure 7a. This effective triangulation is based on the inter-player distances. This kind of defence is difficult for the opposing team to overcome since it does not leave much free space to play. Hence, if team A ensures such effective triangulations they can strengthen their defensive positioning and cope with the offensive mission of the opposing team. Furthermore, the example presented in Figure 7a shows a higher tendency to ensure the defensive principle of concentration. Also, it is possible observe a considerable distance between teams' centroids as well as an angular offset (centre of the circumferences). The angular offset between centroids means that team A presents a tendency to maintain the strong defence uniformly distributed within the field's width (y-axis) while the opponent opts to attack by the left side. It is also possible to observe that team B shows a higher stretch index when compared to team A (radii of the circumferences). This situation is normal considering the principles of play with and without ball possession.

Team A still does not have the ball possession in Figure 7b but the analysis differs from the previous example. This figure depicts an alarming tactical behaviour. Only two effective triangles were generated due to the irregular and abusive dispersion of teams A players while in a defensive phase. This situation may generate opportunities for the opposing team to explore the open spaces. Also, it can be observed that the centroids are very close to each other. These situations are strongly associated with opportunities to shoot or score [22]. Therefore, the equilibrium between both teams is effectively reported by the proposed metrics among these two different situations.

Let us now analyse a couple of examples wherein team A has the ball possession (Figure 8). Figure 8a shows that team A presents a higher effective area of play. It is possible to observe a high number of effective offensive triangles. This represents a wide range of successful offensive opportunities. As the stretch index of both teams is high, team A, as the ball's possessor, may explore the spaces left by the opposing team. In this example, the team A centroid tends to the right side while the opponent maintains a uniform distribution along the field's width. The closeness between centroids and their location suggests that team B tries to defend near the middle region in the field and not as close to their own goal as team A did in Figure 7.

Figure 8b shows that the forward player from team A has the ball possession. Nevertheless, the offensive coverage is broken by the effective area of play generated by team B in the middle side closer to their own goal. This protection is highly important as it significantly reduces the offensive opportunities of team A. If such a situation had not been verified, the defensive team would be unbalanced and the opportunity to further explore offensive strategies would be advised. As team A centroid is near the middle of the field, the support efficiency to the forward player is questionable; i.e., the union principle is not verified due to the high distance between players. Nevertheless, this situation may represent a specific feature of team A offensive strategy, that only can be observed after further plays.

Many other examples could be provided to explain the potentiality of the proposed metrics. These metrics were not designed to replace any other kind of analysis, but to complement those. It is important to consider further improvements to increase the potentialities of those tactical metrics.

In sum, the proposed metrics provide a wide range of information that may complement the classical analysis. Further studies should be conducted on notational indicators and tactical metrics, merging the whole on-the-fly information and improving the pertinence and usefulness of such metrics within the development of new devices for coaches and analysts.

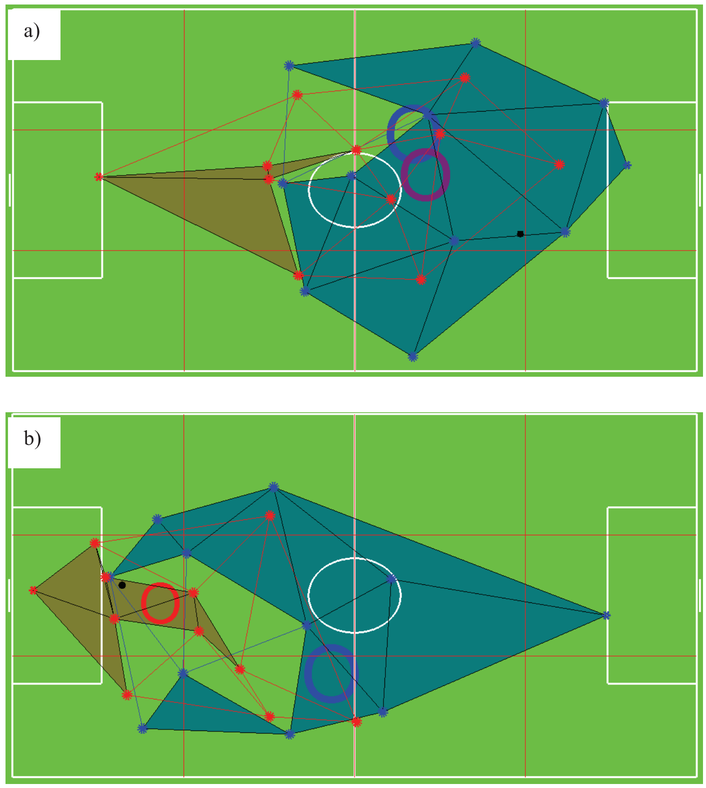

Figure 8. Team A (Blue) with Ball Possession

CONCLUSION

This study aimed to analyse the tactical responses of the two teams at two different moments: with and without ball possession. The team's weighted centroid, the weighted stretch index, the surface area and the effective area of play were explored in an on-line fashion to retrieve quantitative information about the collective behaviour. The study of the tactical dimension of teams allows verification of the differences between the collective behaviour in the states with and without ball possession. While in ball possession, players usually converge to the opponent's half of the field. This increases the dispersion level of players in relation to the centroid and expands the effective play area of the team; i.e., all tactical responses correspond to the tactical principles such as the width and length of the team as well as the offensive unit. However, in the defensive phase (i.e., without ball possession) teams retract their weighted centroid position. In other words, players usually converge to their half field, which decreases players' dispersion in relation to the weighted centroid position and reduces the effective area of play in respect of the tactical principles of the concentration and defensive unit.

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