Towards A New Method to Analyze The Soccer Teams Tactical Behaviour: Measuring The Effective Area of Play

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Abstract

Recently, new tactical metrics have been developed to increase the match analysis' potential. Naturally, innovate metrics need some updates in order to improve the utility to the soccer coaches. Thus, this paper aims to update the surface area metric, proposing the effective area of play given some efficacy information's about team players' positioning. Furthermore, aim analyzes the effective area of play of each team depending on the state of ball possession and a full match of 7-a-side soccer game in the district final was also analysed. Results showed an inverse correlation between teams' opposite effective areas of play(r_p= -0.681), suggesting the expansion-contraction relationship. Furthermore, was analyzed statistical differences with large effect between the moments with and without ball possession for the team A ($F_{(1; 1506)}$ = 1343.893; *p-value* ≤ 0.001; η^2= 0.472; *Power* = 1.000) and B ($F_{(1; 1506)}$ = 968.500; *p-value* ≤ 0.001; $\boldsymbol{\eta^2}$= 0.391; *Power* = 1.000).

***Keywords*:** Match analysis; Tactics; Soccer; Effective area of play.

1. Introduction

The logic, the tactic and the practice constitutes as a notions that involve two main and associated ideas (Gréhaigne, Richard & Griffin, 2005): i) the reality of the game is intelligible and ii) the intervention in the reality can be the subject of objective, thus rational inquiry. Therefore, some authors advocate that the essence of game style is property of their players (*e.g*., Deleplace, 1995; Wade, 1970). The statement emphasizes that players have the higher influence in the play styles' evolution, considering that the application is performed by them (Gréhaigne, Richard & Griffin, 2005). Coaches, referees and play rules, constitutes as complementary factors that influence the game.

The own properties of the sport games constitute as a fundamental constraint to the potentiality improvement of the players (Almond, 1986). Therefore, the match analysis need consider relevant factors that determine the quality of collective performance in function of the rapport of strengths between opposite teams, as well as the competency network between teammates (Gréhaigne, Richard & Griffin, 2005). The knowledge about relationship of the opposite teams and their style of play constitutes as essential information to the efficacy of match analysis.

Match analysis refers to the objective of recording and examining events occurring during competition (Carling, William & Reilly, 2005). The main goal of match analysis is to provide the coach relevant information about the team and/or the individual performance of each player (Franks & McGarry, 1996), thus allowing to improve the quality of future planning (Hughes & Franks, 2004). At the same time, the coach can analyze the performance of the opposing team (Clemente, Couceiro, Martins & Mendes, 2012) in order to use the data to identify ways to overcome its strengths and exploit its weaknesses (Carling, Reilly & Williams, 2009).

Several analysis methods have been developed improving the systemic understanding about the quality of play of the opposing teams, as well as the team itself aiming to increase the quality of the action at the time of opposition. Summarily, the match analysis has been grouped into three levels of analysis: i) technical analysis; ii) tactical analysis and iii) kinematic analysis. Nevertheless, for the technical and tactical analysis, the methodology adopted is essentially related to notational analysis, revealing itself as important but not enough to achieve high quality of information to the coaches (Clemente, 2012). Thus, through the notational methods commonly used, the process of interpreting results may be hampered (Lees, 2002). Therefore, notational analysis determines the product but not analyzes the processes that originate outcomes.

Considering the exposed above, new tactical metrics has been suggested recently to increase and improve the quality of the information provided by match analysis methods. One of the fundamental tactical metrics relates to the spaces of play, trying understanding the collective tactical behaviour of soccer teams, namely the fundamental principles of defensive concentration (*i.e.*, contraction) and offensive width and length (*i.e.*, expansion), confirming the inverse contraction-expansion relationship between teams in function of their state of ball possession (Costa, *et.al.,* 2010).

1.1 Related Works

1.1.1 Effective Play-Space

The first concept related to spaces of play was introduced by Gréhaigne (1992) designating him by effective play-space. This concept is characterized by the system shaped by all lines that limit the field. The observable variables are the successive positions of the players in the t instant in the team's periphery. According to Gréhaigne (1992) goalkeepers are not taken into account. The players' positions define a surface polygon of the team. Through the effective play-space, Gréhaigne (1992) suggested the possibility to analyze the rapport of strength between opposite teams. Nevertheless, the existent tracking resources and tools in 1992 do not allowed a computational application of this method over time automatically.

In addition to the effective play-space concept Gréhaigne, Richard and Griffin (2005), developed other two analysis categories: *i*) dominant distribution of the players and *ii*) covered play space. For the first concept it is suggested that it can use dominant distribution to assess how players interact and interpret the rapport of strength and their own positions. The dominant distribution is based on the players' position around the player with ball possession. However, Gréhaigne, Richard and Griffin (2005) do not suggest any algorithm to apply this dominant distribution concept. The second concept (*i.e.*, covered play-space) is characterized by the area representing the space occupied by attackers and defenders during an offensive play. According to Gréhaigne, Richard and Griffin (2005) it defines the maximum space area covered by the players throughout a sequence of play. Similarly to dominant distribution, none algorithm is suggested to perform this method. Thus, despite of all metrics proposed by Gréhaigne showed an unquestionable pertinence, until 2008 none computational automatic application was performed.

Considering the effective play-space and the state of ball possession (*e.g.*, Gréhaigne, 1992; Gréhaigne, Richard & Griffin, 2005), Gréhaigne, Godbout and Zerai (2011) suggest an update, namely the offensive effective play-space and defensive effective play-space. Particularly, in the defensive effective play-space are suggested two notions: *i*) in block; and *ii*) in pursuit. Gréhaigne, Godbout and Zerai (2011) consider that defense is in block when it is generally positioned between the ball holder, the attackers and its own goal. The state in pursuit is considered when it is generally positioned behind the ball holder, the attackers and its goal (Gréhaigne, 1990). Thus, a defense in pursuit is momentarily out-of-position, *i.e.*, unbalanced. Therefore, this metrics can give some information about the range of time that team spends in their defensive moment in pursuit and in block. Nevertheless, once again Gréhaigne suggests a useful idea, although without showing applications or computation's suggestions.

1.1.2 Surface Area

The surface area can be defined as the total space covered by a team, referred to as the area within the convex hull (Frencken, *et.al.,* 2011). The surface area method is proposed by Frencken and Lemmink (2008) trying complementing the centroid metric because their outcome does not give information about the players' distribution on the field. Thus, the surface area represents overall team's position. Frencken and Lemmink (2008) conducted a pilot study using a four-a-side game as a test to implement the surface area metric. Using the Local Positioning Measurements, the players' coordinates were obtained. For the analysis, only attacks that resulted in goal-scoring opportunities, following a critical incident were considered, resulting in nine attacks were analyzed. Before the study, it was expected an inverse correlations between surface areas of the teams. According to the fundamental tactical principles, the surface area should be larger for the attacking team when compared to the defensive team. The results of the pilot study did not show a clear anti-phase relation between teams surface areas. Nevertheless, the four-a-side game is strongly dynamic and the fundamental principles may not have been performed. Thus, surface area might not be a useful dependent variable to use form small-sided games (Frencken & Lemmink, 2008).

Despite the suggestions given by Frencken and Lemmink (2008) about the efficacy of the surface area in small-sided games, Frencken *et.al.,* (2011) tried the tactical metric in the five-a-side game. Thus, ten young elite male soccer players were tested in 3 matches with 8 minutes. For the surface area calculus, two measures were considered: length (m) and width (m). Length was defined by the distance between the most backward and forward player (representing the x-axis). Width was defined as the distance between the most lateral players on either side of the field (representing the y-axis). Thus, the surface area is the total space covered by a team, referred to as the area within the convex hull (Frencken, *et.al.,*2011). The convex hull is calculated determining firstly a pivot point, in this case, the lowest y-value player. If there were multiple, then the player with the highest x-value was the pivot point. Then, the angle from the pivot to each player was calculated. Players were sorted by angle and removed if not part of the convex hull. An arbitrary point within the convex hull, here the centroid, was taken to create a triangle with the player that was designated as pivot and one of the remaining players. Therefore, the area was calculated by adding the triangles of consecutive points of the convex hull and the centroid. The calculus of the surface area not integrates the ball possession or their localization, *i.e.*, only considers the players. The sample used by Frencken *et.al.,* (2011) was all 19 goals scored in the three games. When a goal was scored, the surface area was visually inspected from the time that the ball possession was won until the goal.

Similar to the results obtained in Frencken and Lemmink (2008), Frencken *et.al.,* (2011) showed that r-pearson correlation coefficients are lower between teams' surface area. Correlations values are for length between 0.30 and 0.36, for width between – 0.01 and – 0.03 and for surface area between – 0.01 and 0.07. These results imply no linear association for the surface areas of the teams. Nevertheless, it is important to remember that small-sided games despite of characterize some points of the 11-a-side game does not allow an intrinsic perception about collective behaviour in relation to fundamental tactical principles because small-sided games presents less levels of the structured game.

Using 20 players resulted in shots on goal, without ball aerial trajectories and change of ball possession between teams in the 3 v 3 soccer sub-phases, Duarte *et.al.,* (2012) analyzed the surface area for three players (A, B and C). The surface area of each team was calculated as the area of a triangle, considering the Cartesian coordinates:

$$Area(A,B,C) = \frac{abs\big((xB\times yA - xA\times yB)+(xC\times yB - xB\times yC)+(xA\times yC - xC\times yA)\big)}{2}, \quad (1)$$

Continuous correlation functions performed by Duarte *et.al.,* (2012) showed high variations in the correlation values, indicating the irregular coordination of the teams during the play. Nevertheless, the results also showed evidences of global coordination tendencies between opposite teams, without a strong confirmation. Thus, Duarte *et.al.,* (2012) suggested that in 3 v 3 soccer sub-phases of play, it seems that teams increase or decrease their surface area independently of the opposite team's behaviour. Results also suggested through the variance analysis that differences between teams progressively increased along three key moments of performance (*e.g.*, ball control, assisted pass and crossing line). Analyzing the post hoc tests itwas found that the differences were observed only at the moments of the assisted pass and when the ball crossed the defensive line suggesting the importance of increasing the surface area to the attacking sub-groups in order to unbalance the opposite team and create shooting opportunities (Gréhaigne, *et.al.,* 1997). Nevertheless, similarly to previous studies (*e.g.*, Frencken & Lemmink, 2008; Frencken, *et.al.,* 2011), the surface area does not reveal conclusive and robust results in small-sided games. Thus, this metric should be analyzed only in 11-a-side game in order to integrate the fundamental and ecological principles of the game.

Using the same method that Frencken *et.al.,* (2011), Bartlett *et.al.,* (2012) analyzed the teams' surface area of 305 plays recorded in 5 professional soccer games. The outcomes provided by their study did not support the theoretical inverse relationship of the concentration and expansion behaviour of the teams. The expansion-contraction pattern was apparent for only 28% of the attacks across the five games for surface area. Nevertheless, as previously discussed, the five game analyzsis did not consider the teams that won or lost; the 5 games can be performed by ten different teams. Thus, the results do not demonstrate the reality of the one team but yet it provided an erroneously mixed samples.

1.1.3 Coverage Area

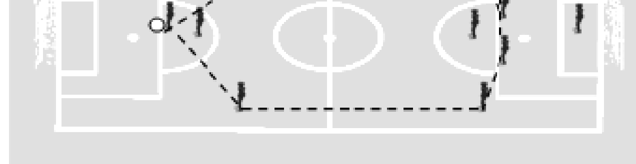
The concept of team coverage area was analyzed computationally for the first time by Okihara, *et al.,* (2004). Recording two professional matches, the Direct Linear Transformation method was performed to obtain the players' coordinates on the field. In the first match, only four players were analyzed by team that occupied, in the team A 92.3 ± 59.5 m^2 when attacking and 51.0 ± 33.6 m^2 when defending. In the team B, the average area was 77.7 ± 50.6 m^2 when attacking and 46.9 ± 36.0 m^2 when defending. The second match analyzed was the Japan v UAE. In first half the average of the Japan team was 1645 ± 546.5 m^2 when attacking and 1220.9 ± 483.0 m^2 when defending, while that of the UAE team was 1379.6 ± 570 m^2 when attacking and 1232.4 ± 467.9 m^2 when defending. In the second half, the average area for the Japan team was 1703 ± 569.2 m^2 when attacking and 1207.1 ± 631.8 m^2 when defending, while that of UAE team was 1428 ± 553.5 m^2 when attacking and 1392.4 ± 460.9 m^2 when defending. The results suggest that compactness behaviour of the teams when defending decreases the coverage area and a large polygon shape when attacking increases the coverage area.

Using an automatic tracking method based on direct linear transformation, Moura *et.al.,* (2012) obtained the trajectories of 223 soccer players in the eight games of Brazilian First Division Championship between 16 different teams. At the same time, the ball possession was recorded in order to analyze the team coverage area in the defensive and offensive status. Moura *et.al.,* (2012) used the convex hull area to analyze the team covers. The convex hull of a set of points S (*i.e.*, each player's position on the same team in each t instant) on a plane is the smallest convex set containing S; if S is finite, the convex hull is always a polygon whose vertices are a subset of S. The convex hull was computed by Moura *et.al.,* (2012) through the Quickhull technique. Thus, at each t instant the convex hull of the team was divided in triangles to aid the calculation of the convex hull area (*i.e.*, summing the areas of all triangles within the convex hull).

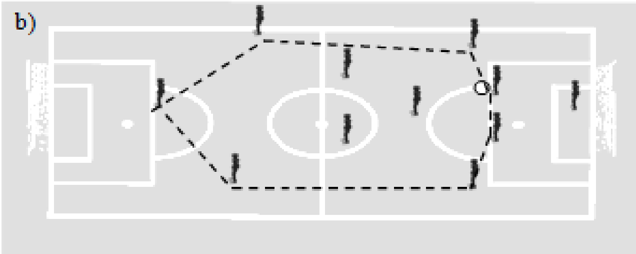
Results of the Moura *et.al.,* (2012) showed an increase of the coverage area values when teams had the ball possession comparatively with the moments without ball possession. The average of team' coverage area in defensive status when tackles were performed was 920.7 ± 13.3 and when teams suffered shots on goal 1110.4 ± 41.7. In the offensive status, the average of team' spread when teams suffered tackles was 1059.6 ± 15.2 and when shots to goal were performed 898.9 ± 43.9. Nevertheless, the coverage area temporal-series did not present an unequivocal anti-phase relation.

1.1.4 Summary of Spaces of Play

Fig.1. *Example of Surface Area for two different positioning*



ing market to offer sufficient housing with appropriate cost. This



All metrics analyzed only provide information about the polygons formed through the positioning of the players. Nevertheless, this information may be sparsely to the coach. The same polygon and/or the coverage area may be different (Figure1), representing different qualities of tactical performances.

Considering the previous figure (1b), a higher structural organization of the players distribution can be possibly analysed. Nevertheless, for the current surface area method the area of play is equal, not providing relevant information about the positioning quality. Thus, an update need to be considered in order to improve the information provided to the coach. 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.

1.2 Statement of Contribution

Soccer tactics can be geometrically analyzed to further understand how team behaves. Lucchesi (2001) refers that the geometric figures that allow the most successful play along the field are triangles. The author enhances that the ability of the team to "draw up" such triangles on the field allows developing a good offensive play. 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 owing to the triangular-shaped positioning of players (Dooley & Titz, 2011). Therefore, as the number of formed triangles within a team increase, the less effective space is left for the opposing team.

For instance, Trapattoni (1999) affirmed that when players are pressured and cannot turn around and dribble, the ball must travel along triangles until a solution for forward play is found, *i.e.*, the offensive triangles are annulled by the defensive triangles. In the presence of interceptions between opposing triangles, and based on the supposition that effective defensive triangles can annul the offensive triangles (Trapattoni, 1999), the effective area to be considered is the one of the defensive triangles, thus reducing the effective area of the offensive team. However, Dooley and Titz (2011) proved that in order to form effective defensive triangles, it is necessary to have an approximate distance of 12 meters between each vertex (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, it will be nullified by the offensive triangles since there are no guarantees that the defensive players will be able to intercept the ball. Thus, for a surface area update should be considered the number of efficacy triangulations formed by teams according to the theoretical norms provided previously.

Therefore, the main goal of this paper is to present a new soccer tactical metric trying proving their contribution and pertinence to help the coaches' understanding about the collective team's behaviour, comparing the surface area method and the effective area of play. Furthermore, will be analyzed the special contraction-expansion relationship between teams in function to the state of ball possession. Through this work will be highlighted the effective area of play contribution to new online soccer analysis technologies.

2. Materials and Methods

2.1 Sample

The tactical metrics were evaluated in a 7-a-side soccer game. The analyzed match was the district final of under-13 soccer. Teams' actions were captured using a digital camera (GoPro Hero with 1280 x 960 resolution), with capacity to process images at 30 Hz (*i.e.*, 30 frames per second). The camera was placed above the ground in order to capture the whole game. This study was conducted within the guidelines of the American Psychological Association and the protocol received approval from a local university ethics committee.

2.1.1 Procedures

After capturing the soccer match through the camera, the physical space was calibrated using direct linear transformation (*i.e.*, DLT), which transforms elements' position (*i.e.*, players and ball) to the metric space (Duarte, *et.al.,* 2010). 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.

2.2 Effective Area of Play Computation

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 N players, in which N is the total number of players within a team.

Algorithm 1. Calculate the surface area of the team.

Alg:1
For $i = 1: N - 2$
  For $j = i + 1: N - 1$
    For $k = j + 1: N$
      $l = l + 1$
      $\Delta_l = \begin{bmatrix} x_i & x_j & x_k \\ y_i & y_j & y_k \end{bmatrix}^T$ // each triangle is defined by the position of three different players
$P = \Delta_1$ // initialize the polygon as the first triangle defined by players 1, 2 and 3
For $i = 2: l$
  $P = P \cup \Delta_i$, $where\ P = (p_1, \ \cdots, \ p_\alpha)\ and\ \alpha \leq N$ // build the polygon by accumulatively uniting itself to the remaining triangles
$A_{Pol} = \frac{1}{2}\sum_{i=1}^{\alpha-1}\left(p_{1,i}p_{2,i+1} - p_{1,i+1}p_{2,i}\right)$, $with\ \alpha \leq N$ // calculate the area of the polygon

The first objective after considering the surface area is to calculate all the non-overlapping triangles formed by the players of the same team.

Algorithm 2. Calculate the surface area of team with non-overlapping triangles.

$l^\delta = 0$ // counter of the combinations of N players of team δ taken three at a time
For $i = 1: N^\delta - 2$
  For $j = i + 1: N^\delta - 1$
    For $k = j + 1: N^\delta$
      $l^\delta = l^\delta + 1$
      $\Delta_l^\delta = \begin{bmatrix} x_i & x_j & x_k \\ y_i & y_j & y_k \end{bmatrix}^T$ // each triangle is defined by the position of three different players
      $\rho_l = \sum_{i=1}^{3}\left\|\left(x_i - x_j\ ,\ y_i - y_j\right)\right\|$, $with\ i \neq j\ and\ i < j$
$\vec{s} = sort\_ascending\ (\vec{\rho}) \in \mathbb{R}^{1\times\beta}$, $where\ \vec{\rho} = (\rho_1, \ \cdots, \ \rho_\alpha)\ and\ \beta = \binom{N^\delta}{3}$
$P^\delta = \Delta_{s_1}^\delta$ // initialize the polygon as the triangle with the smallest perimeter
$\Delta_1^\delta = \Delta_{s_1}^\delta$ // initialize the non-overlapping triangles of team δ
$\tau^\delta = 1$ // counter of the non-overlapping triangles of team δ
For $i = 2: l^\delta$
  $\Gamma = P^\delta \cap \Delta_i^\delta$, $where\ \Gamma = (\gamma_1, \ \cdots, \ \gamma_\alpha)\ and\ \alpha \leq N^\delta$ // analyze intersections between triangles
  $A_{Pol} = \frac{1}{2}\sum_{i=1}^{\alpha-1}\left(\gamma_{1,i}\gamma_{2,i+1} - \gamma_{1,i+1}\gamma_{2,i}\right)$ $with\ \alpha \leq N^\delta$ // calculate the area of the intersection
  If $A_{Pol} = 0$ // condition is verified when there is no intersection between triangles
    $\tau^\delta = \tau^\delta + 1$
    $P^\delta = P^\delta \cup \Delta_i^\delta$ // build the polygon by accumulatively uniting the non-overlapping triangles
    $\Delta_{\tau^\delta}^\delta = \Delta_i^\delta$ // non-overlapping τ^δ triangle of team δ

The main condition to this is to generate, at first, the triangles with smaller perimeters (Figure 2).

Figure.2. *Example of Surface Area Calculation*

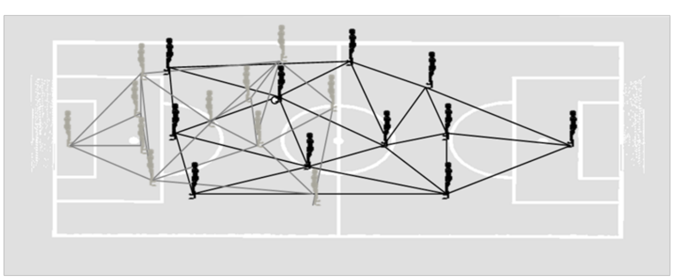
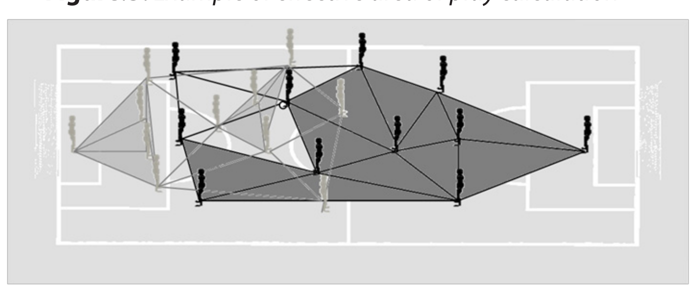


Figure.3. *Example of effective area of play calculation*



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.

Algorithm 3. Effective Area - Triangles of team δ that do not intersect the surface area of the opposing team ζ .

$A^{\delta} = 0$ // effective area of team δ
$E^{\delta} = [\,]$ // polygon of the effective area of team δ is initialized as an empty array
For $i = 1{:}\,\tau^{\delta}$
  $\Gamma = \Delta_i^{\delta} \cap P^{\zeta}$, $where\ \Gamma = (\gamma_1, \ \cdots, \ \gamma_\alpha)\ and\ \alpha \le 6$ // analyse intersections between triangles
  $A_{Pol} = \frac{1}{2}\sum_{i=1}^{\alpha-1}(\gamma_{1,i}\gamma_{2,i+1} - \gamma_{1,i+1}\gamma_{2,i})\ with\ \alpha \le 6$ // calculate the area of the intersection
  If $A_{Pol} = 0$ // condition is verified when there is no intersection between the triangle from team δ and the surface area of team ζ
    $A_{Pol} = \frac{1}{2}\sum_{i=1}^{3}(x_i y_{i+1} - x_{i+1} y_i)$ // 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
    $E^{\delta} = E^{\delta} \cup \Delta_i^{\delta}$ // build the polygon of the effective area of team δ by accumulatively uniting its effective triangles

In algorithm 3, both teams are simultaneously considered in which δ and ζ are the team *ID* such that δ = 1,2 and ζ = 1,2 with δ ≠ ζ.

Dooley and Titz (2011) proves that 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 defensive triangles have a perimeter superior to 36 meters, it will be nullified by the offensive triangles since there are no guarantees that the defensive players will be able to intercept the ball.

Thus, 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 (Algorithm 4).

Algorithm 4. Effective Area - Defensive triangles of team δ that intersect the surface area of the opposing team ζ.

If $ball\_possession(\zeta) = 1$ // condition is verified when team ζ has the possession of the ball
For $i = 1{:}\,\tau^{\delta}$
  $\Gamma = \Delta_i^{\delta} \cap P^{\zeta}$, $where\ \Gamma = (\gamma_1, \ \cdots, \ \gamma_\alpha)\ and\ \alpha \le 6$ // analyse intersections between triangles
  $A_{Pol} = \frac{1}{2}\sum_{i=1}^{\alpha-1}(\gamma_{1,i}\gamma_{2,i+1} - \gamma_{1,i+1}\gamma_{2,i})\ with\ \alpha \le 6$ // calculate the area of the intersection
  $\rho_{Pol} = \sum_{i=1}^{3}\left\|(x_i - x_j\ ,\ y_i - y_j)\right\|$, $with\ i \ne j\ and\ i < j$
  If $A_{Pol} > 0\ and\ \rho_{Pol} \le \rho_{\varepsilon}$ // 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

At last, all offensive triangles that are not intercepted by the defensive triangles with perimeter inferior to 36 meters are considered (Figure 3).

Alg:5 Consequently, the algorithm calculates all triangles, thus calculating the respective effective areas of both teams at every instant (Algorithm 5).

Algorithm 5. 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 $i = 1{:}\,\tau^{\delta}$
  $\Gamma = \Delta_i^{\delta} \cap (P^{\delta} \cup P^{\zeta})$, $where\ \Gamma = (\gamma_1, \ \cdots, \ \gamma_\alpha)\ and\ \alpha \le 6$ // analyze intersections between offensive triangles and the effective area of both teams
  $A_{Pol} = \frac{1}{2}\sum_{i=1}^{\alpha-1}(\gamma_{1,i}\gamma_{2,i+1} - \gamma_{1,i+1}\gamma_{2,i})\ with\ \alpha \le 6$ // 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 2

Considering the optimized version for online analysis, the processing takes about 0.98 seconds in a *intel 4 core 2 quad cpu q900 processor 2.0 GHz and 4 GB of RAM.* It is important to consider that the time cannot be substantially reduced since the graphical representation requires a significant processing time. Nevertheless, it would be possible to reduce the processing time using C++ instead of *MatLab.*

2.3 Statistical Procedures

The one-way ANOVA was used to analyze the statistically significant differences between teams with and without ball possession, as well as to comparing the surface area and effective area of play. The assumption of normality distribution 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 (Maroco & Bispo, 2003; Pedrosa & Gama, 2004), was assumed the assumption of normality (Akritas & Papadatos, 2004). 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 (Vicent, 1999; Pestana & Gageiro, 2008; Maroco, 2010), which is our case. As with the assumption of normality, violation of this assumption does not radically change the F value (Vicent, 1999). 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 (2010) and Pallant (2011). This analysis was performed using the IBM SPSS program (version 19) for a significance level of 5%.

3. Results and Discussion

3.1 Comparing Surface and Effective Play Area

In first instance, the main purpose of this paper is comparing the surface area with the effective area of play metric. Thus, considering the univariate analysis of variance test, significance statistical differences between two metrics with medium effect ($F_{(1;\ 6030)} = 780.386$; p-value = 0.001; $\eta^2 = 0.115$; Power = 1.000) was observed. Based on the effective play area, it is possible to observe an inversion of each team's areas (Figure 4). Considering the effective play area, it is possibly observed that Team A shows a higher efficacy in both offensive and defensive triangulations with a mean of 256 m^2 when compared to Team B that presents a mean of 241 m^2. Additionally, the effective play area shows that the classical surface area do not corresponds to a superior efficiency of the team. It should be noted that team A correspond to the team that won the final championship against team B.

Figure.4. *Play Area of two Teams*

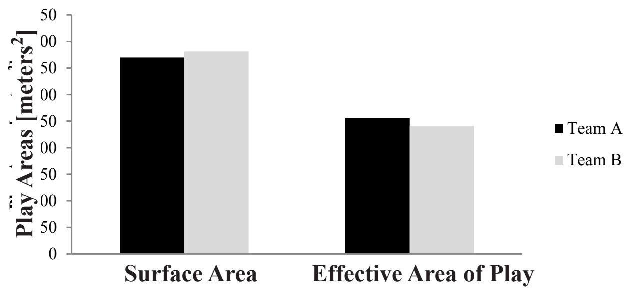
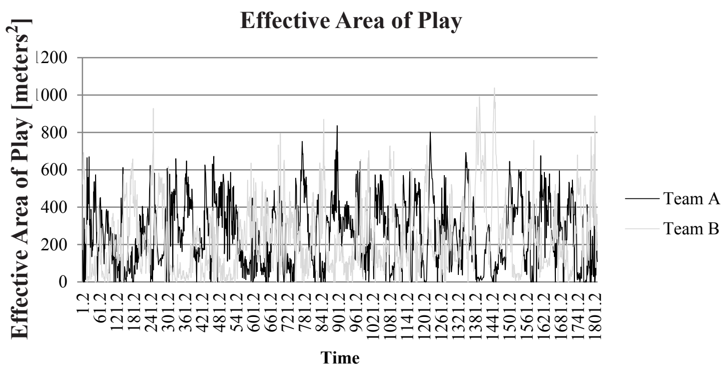


Figure.5. *Effective Area of Play of Team's A and B*



Analyzing the effective play area over time (Figure 5), it is possible to observe permanent inverse cycles of teams.

The quality of the opposition and the response provided by the opposing team can be reported as the rapport of strength that characterizes the soccer game (Gréhaigne, Richard & Griffin, 2005). This rapport of strength may be seen as the relation between the effective areas of both teams. The Pearson's correlation revealed a correlation between the effective play areas of the teams $r_p = -0.681$ which, is an inverse medium correlation.

The automatic tactical metrics recently developed increases and improved the match analysis potentiality. Nevertheless, naturally all innovate processes have some factors that should be updated in order to increase their potential. Thus, the main goal of this paper was to propose a new tactical metric that update the surface area (*e.g.*, Frencken, *et.al.,* 2011; Moura, *et.al.,* 2012; Bartlett, *et.al.,* 2012).

It was mentioned previously, the surface area analyzes the team's polygons generated by all team players. Nevertheless, the polygon inside players does not contribute to understand the collective behaviour because the ball possession, as well as the effective triangulations established by players was not considered. Furthermore, generally the studies based on surface area (*e.g.*, Frencken, *et.al.,* 2012; Bartlett, *et.al.,* 2012) do not confirm the fundamental tactical relation between two opposite teams during the match, *i.e.*, the expansion-contraction relationship. The results obtained in Frencken and Lemmink (2008), Frencken *et.al.,* (2011) showed that r-pearson correlation coefficients are lower between teams' surface area. Correlations values are for length between

0.30 and 0.36, for width between – 0.01 and – 0.03 and for surface area between – 0.01 and 0.07. The outcomes from Bartlett *et.al.,* (2012) showed that expansion-contraction pattern was apparent for only 28% of the attacks across the five games for surface area.

Opposing the outcomes provided by surface area, the effective area of play showed the expectable expansion-contraction relationship through the inverse correlation between teams. The inversion between both effective areas reported above can be originated by the constant opposition, *i.e.*, in the offensive phase, the team's amplitude should be higher (*i.e.*, expansion) in order to unbalance the opponent defensive strategy and inversely, in the defensive phase, the dispersion between teammates should be reduced to conserve the number of effective triangles (*i.e.*, contraction). Nevertheless, the number of effective triangles does not ensure a higher covering area. For instance, if the team is in the offensive process (*i.e.*, with ball possession) and do not have any opponents intercepting the triangulation formed by the defensive players and the goalkeeper, just this triangle substantially contributes for the covering area. Inversely, during the defensive phase (*i.e.*, without ball possession) the effective triangles are only formed if the dispersion between three players does not exceed a perimeter of 18 *m*. May be in previous works the surface area cannot be analyzed for significant inverse results because of not considering the effective triangulations formed by players, as well as the state of ball possession.

Obviously, it can be discussed tthat he effective defensive perimeter proposed in this paper, nevertheless, is an update that can be tested with further biggest sample. Thus, it may be an interesting analysis to have the same team throughout full season. The same team guarantees similar models of play, *i.e.*, the same playing style. When compared different teams' surfaces, naturally the average results may not provide consistent results. Thus, the full season guarantees important information about the team and their behaviour along the time.

3.2 Comparing the Play Areas considering the state of Ball Possession

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

Table 1. *Mean results of Surface Area and Effective Area of Play*

Team	State of Ball Possession	Surface Area		Effective Area of Play	
		Mean	Stand. Dev.	Mean	Stand. Dev.
Team A	With Ball Possession	3783.65	1489.63	3511.82	930.91
	Without Ball Possession	3551.41	1571.74	1023.63	1458.40
Team B	With Ball Possession	4170.17	1818.05	3943.03	1836.41
	Without Ball Possession	3589.61	1766.91	1457.72	1261.45

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 3511.82m^2 and 1023.63m^2 without ball possession. These differences are statistically different with large effect between them ($F_{(1;\ 1506)}$ = 1343.893; p-value ≤ 0.001; η^2 = 0.472; Power = 1.000). Similar results are found in the case of team B, where the mean with ball possession is 3.943m^2 and 1457.72m^2 without it. The variance analysis shows statistical differences with large effect ($F_{(1;\ 1506)}$ = 968.500; p-value ≤ 0.001; η^2= 0.391; Power = 1.000).

The ball possession is constrained by the match status or the opposite team (Lago & Martín, 2007). 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 (Hughes & Franks, 2005). Thus, 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 (Lago-Peñas & Dellal, 2010). Therefore, the tactical behaviour will be necessarily different depending on the state: with or without ball possession.

According to the concentration and unit tactical principles in defensive phase (Costa, *et.al.,* 2010), 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 (Costa, *et.al.,* 2010). 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. Thus, the state of ball possession determines the coverage area, as well as the triangulation effectiveness.

4. Practical Application

The application developed and presented during the methodology section presented a main reference to coaches or analysts. It presents a graphical user interface that allows observing the instantaneous effective area of play during the moments with or without ball possession, *i.e.*, allowing the observation of the number of effective triangulations performed by team players in order to achieve their own goals. This visualization allows further understanding about the team's contraction and expansion, improving the opportunity to measure the respect by team tactical principles. Through this measurement it can be readjusted that the team's behaviour or fit the collective strategy to the opponent's tactical behaviour, allowing explore their weaknesses and avoid their strengths. Also, this method can be adjusted to coaches' needs, improving the offer in a commercial way. Thus, kind of functionality can be easily interconnected to automatic tracking systems (*e.g.*, ProZone®, Amisco Pro®), so as to allow the computation of such metrics in an online fashion.

5. Conclusion

The main goal of the present study was to analyze a new tactical metric that provide an effective vision about the effective play area covered by a team. Furthermore, aims to analyze the effective play area differences between the states with and without ball possession. The correlation between teams' effective area of play shows an inverse correlation relationship suggesting a contraction-expansion relation, corresponding to the fundamental principles of defensive concentration and offensive width and length.

Through the study of tactical dimension of the teams, it was possible to verify the differences between the collective behaviour in the states with and without ball possession. With ball possession, teams significantly increase their effective area of play, expanding the possibilities of action. On the other hand without ball possession, teams' effective area of play decreased, corresponding to the defensive concentration, *i.e.*, contracting the team's dispersion.

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7. References

1. Akritas, M. G., & Papadatos, N. (2004). Heteroscedastioc One-Way ANOVA and Lack-of-Fit Tests. Journal of the American Statistical Association, 99 (466), 368-390.
2. Almond, L. (1986). Primary and secondary rules in games. In R. Thorpe, D. Bunker, & L. Almond (Eds.), Rethinking games teaching (pp. 73-74). Loughborough, England: Loughborough University of Technology.
3. Bartlett, R., Button, C., Robins, M., Dutt-Mazumder, A., & Kennedy, G. (2012). Analysing Team Coordination Patterns from Player Movement Trajectories in Soccer: Methodological Considerations. International Journal of Performance Analysis in Sport, 12(2), 398-424.
4. Bourbousson, J., Sève, C., & McGarry, T. (2010). Space-time coordination dynamics in basketball: Part 2. The interaction between the two teams. Journal of Sports Sciences, 28(3), 349-358.
5. Carling, C., Reilly, T., & Williams, A. (2009). Performance assessment for field sports. London: Routledge.
6. Carling, C., Williams, A. M., & Reilly, T. (2005). Handbook of soccer match analysis: A systematic approach to improving performance. Abingdon, UK: Routledge.
7. Clemente, F. M. (2012). Study of successful soccer teams on FIFA World Cup 2010 through notational analysis. Pamukkale Journal of Sport Sciences, 3(3), 90-103.
8. Clemente, F., Couceiro, M., Martins, F., & Mendes, R. (2012). Team's Performance on FIFA U17 World Cup 2011: Study based on Notational Analysis. Journal of Physical Education and Sport, 12(1), 13-17.
9. Costa, I. T., Garganta, J., Greco, P. J., Mesquita, I., & Seabra, A. (2010). Influence of Relative Age Effects and Quality of Tactical Behaviour in the Performance of Youth Soccer Players. International Journal of Performance Analysis in Sport, 10(2), 82-97.
10. Deleplace, R. (1995). Logique du jeu et conséquences sur l'entraînement à la tactique. Communication orale "Colloque sport collectif". Paris: INSEP.
11. Dooley, T., & Titz, C. (2011). Soccer – The 4-4-2 System. Germany: Meyer & Meyer Sport.
12. Duarte, R., Araújo, D., Fernandes, O., Fonseca, C., Correia, V., Gazimba, V., Travassos, B., Esteves, P., Vilar, L., & Lopes, J. (2010). Capturing complex human behaviors in representative sports contexts with a single camera. Medicina (Kaunas), 46(6), 408-414.
13. Duarte, R., Araújo, D., Freire, L., Folgado, H., Fernandes, O., & Davids, K. (2012). Intra- and inter-group coordination patterns reveal collective behaviors of soccer players near the scoring zone. Human Movement Science, DOI: 10.1016/j.humov.2012.03.001
14. Franks, I. M., & McGarry, T. (1996). The science of match analysis. In T. Reilly (Ed.), Science and Soccer (pp. 363-375). Oxon: Spon Press Taylor & Francis Group.
15. Frencken, W., & Lemmink, K. (2008). Team kinematics of small-sided soccer games: A systematic approach. In T. Reilly, & F. Korkusuz (Eds.), Science and Soccer VI (pp. 161-166). Oxon: Routledge Taylor & Francis Group.
16. Frencken, W., Lemmink, K., Delleman, N. & Visscher, C. (2011). Oscillations of centroid position and surface area of soccer teams in small-sided games. European Journal of Sport Science, 11(4), 215-223.

17. Gréhaigne, J. F. (1992). L'organisation du jeu en soccer. Joinville-le-Pont, France: Éditions Actio.
18. Gréhaigne, J. F., Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationship in collective actions in soccer. Journal of Sports Sciences, 15(2), 137-149.
19. Gréhaigne, J. F., Godbout, P., & Zerai, Z. (2011). How the "rapport de forces" evolves in a soccer match: the dynamics of collective decisions in a complex system. Revista de Psicología del Deporte, 20(2), 747-765.
20. Gréhaigne, J. F., Richard, J. F., & Griffin, L. (2005). Teaching and learning team sports and games. New York: Routledge Falmar.
21. Lames, M., Erdmann, J., & Walter, F. (2010). Oscillations in soccer – Order and disorder in spatial interactions between the two teams. International Journal of Sport Psychology, 41, 85-86.
22. Lees, A. (2002). Technique analysis in sports: a critical review. Journal of Sports Sciences, 20(10), 813-828.
23. Lucchesi, M. (2001). Attacking Soccer: A Tactical Analysis. Auburn, Michigan: Reedswain Publishing.
24. Maroco, J. (2010). Análise Estatística com o PASW Statistics [Statistical Analysis with PASW Statistics]. Lisboa: Edições Sílabo.
25. Maroco, J., & Bispo, R. (2003). Estatística Aplicada às Ciências Sociais e Humanas [Applied Statistics at the Social and Human Sciences]. Lisboa: Climepsi Editores.
26. Moura, F. A., Martins, L. E., Anido, R. O., Barros, R. M., & Cunha, S. A. (2012). Quantitative analysis of Brazilian soccer players' organization on the pitch. Sports Biomechanics, 11(1), 85-96.
27. Okihara, K., Kan, A., Shiokawa, M., Choi, C. S., Deguchi, T., Matsumoto, M., & Higashikawa (2004). Compactness as a strategy in a soccer match in relation to a change in offense and defence. Journal of Sports Sciences, 22(6), 515.
28. Pallant, J. (2011). SPSS Survival Manual: A Step by Step Guide to Data Analysis Using the SPSS Program. Australia: Allen & Unwin.
29. Pedrosa, A. C., & Gama, S. M. A. (2004). Introdução computacional à probabilidade e estatística [Introduction Computational Probability and Statistics]. Porto: Porto Editora.
30. Pestana, M. H., & Gageiro, J. N. (2008). Análise de dados para as ciências sociais: A complementaridade do SPSS [Data Analysis for the Social Sciences: The complamentarity of the SPSS]. 5th edition. Lisboa, Portugal: Edições Sílabo.
31. Trapattoni, G. (1999). Coaching High Performance Soccer. Spring City, Pensylvania: Reedswain Inc.
32. Vincent, W. J. (1999). Statistics in Kinesiology (2nd Edition). Champaign: Human Kinetics.
33. Wade, A. (1970). The soccer association guide to training and coaching. London: EP Publishing LTD.