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How dots behave in two different pitch sizes? Analysis of tactical behavior based on position data in two soccer field sizes

¿Cómo se comportan los puntos en dos campos diferentes? Análisis del comportamiento táctico basado en los datos de posición en dos tamaños de campo de fútbol

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Abstract

The purpose of this study was to analyze the effects of two different field sizes (full and half of an official size field) on the tactical behaviors measured by position data of players. Ten amateur soccer players (age = 23.39 ± 3.91 years old) were tracked with GPS units during two situations of 11 vs. 11, one in each field size. The position data was treated and the centroid and stretch index of the team were calculated with the Ultimate Performance Analysis Tool. Significantly greater values of centroid in goal-to-goal axis (p = 0.001; ES = 3.794), centroid in lateral-to-lateral axis (p = 0.001; ES = 0.729) and total stretch index (p = 0.001; ES = 1.185) were found in the full-size game. The full-size of the field increased the distances between teammates and the distances to the centroid. Moreover, the position of geometrical center of the team was beyond of the middle line in the full size.

Key words: GPS; technology; tactical metrics; ultimate performance analysis tool; football; stretch index; centroid.

Resumen

El propósito de este trabajo fue analizar el efecto de la modificación del espacio de juego sobre los comportamientos tácticos en fútbol, mediante variables de posicionamiento de jugadores. Se monitorizó a 10 jugadores amateur (edad = 23.39 ± 3.91 años) con unidades GPS en dos partidos 11 vs. 11 diferentes en cuanto al tamaño del campo (medio campo y campo entero). Se calculó el centroide y el índice de elasticidad de los equipos mediante el software Ultimate Performance Analysis Tool (Instrumento de análisis de alto rendimiento). Se observaron valores significativamente superiores de los centroid portería-a-portería (p = 0.001; ES = 3.794), centroid banda-a-banda (p = 0.001; ES = 0.729) y índice total de elasticidad (p = 0.001; ES = 1.185) en la situación de campo entero. La situación de campo entero incrementó las distancias entre compañeros y distancias de los jugadores respecto al centroide. Además, la posición geométrica del centro del equipo se situó por delante de la línea media del campo en la situación de campo entero.

Palabras clave: GPS; tecnología; evaluación táctica; ultimate performance analysis tool; fútbol; centroid; índice total de elasticidad.

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Introduction

Team sports such as soccer carry a high level of uncertainty and time pressure due to the permanent relationships between players and team's cooperation-opposition dynamics (Gréhaigne, Bouthier, & David, 1997; Serra-Olivares, García-López, & Calderón, 2016). This kind of sport contexts involve a variety of changing environments and a wide diversity of game problems which need to be solved (Davids, Button, Araújo, Renshaw, & Hristovski, 2006). It deals with continuous challenges to the players and teams, who need to develop different abilities to adapt their behaviours to each specific situation, for achieving sport performance (Araújo, Davids, & Hristovski, 2006). For that reason, diverse match analysis techniques (i.e., observational tools, positional data) have been employed to understand the nature of sport tactical behaviours (Serra-Olivares, Clemente, & González-Víllora, 2016).

Match analyses in soccer have been growing in the last decade by studying the players' relative pitch positioning data (Carling, Williams, & Reilly, 2005; Coutts, 2014; Gómez-Ruano, 2017), by using different systems such as radio frequency (W Frencken, Lemmink, Delleman, & Visscher, 2011), video tracking (Di Salvo et al., 2007), and GPS devices (Aughey, 2011). The information about the dots (the players) can be accessed at each instant by considering bidimensional data position. Such information has been contributing to the study of tactical behaviour of players and teams' performance at micro, meso and/or macro levels (Clemente, Couceiro, Martins, Mendes, & Figueiredo, 2013).

Different tactical behaviour indicators regarding inter- and/or intra-player coordination variables have been examined. Some examples are distances (length and width), teams' areas and/or teams' (Surface Area, Effective Area of Play, Territorial Domain, Defensive Play Area) and/or teams' dyads or centroids (Clemente, Couceiro, Martins, Mendes, & Figueiredo, 2014b; Duarte, Araújo, Correia, & Davids, 2012; Travassos, Davids, Araújo, & Esteves, 2013).

Most common indicators have focused on the teams' geometrical centre from the player's positions, the centroid (Duarte et al., 2013; Frencken et al., 2011), and wCentroid (Clemente, Couceiro, Martins, Mendes, & Figueiredo, 2014a). Findings suggest strong coordination patterns between opposing teams centroids (Duarte et al., 2013), although they do not have strong relations to score situations (Frencken, Poel, Visscher, & Lemmink, 2012). Other analyses have showed higher degrees of coordination when players/teams became more offensive, and unpredictable movements of the attackers during the attacking phase (Gonçalves, Figueira, Maçãs, & Sampaio, 2014). In the same line, no relationship has been found between teams' longitudinal and lateral centroid distances with goal scoring situations, but space and temporal reorganization became crucial after ball position changes (Frencken et al., 2012).

Teams/players tend to present regular tactical behaviours along the match in several variables such as areas, length and width (Duarte et al., 2013), although it is necessary to understand if it happens due to the fatigue or the tactical approaches used (Clemente, Couceiro, Martins, Mendes, & Figueiredo, 2013). In this sense, new performance measures such as the wCentroid and the players' dispersion over their centre (wStretch Index) are providing relevant information about the players and teams collective organization. This procedure leads to the identification of in-phase and anti-phase patterns and the tendency to act on a specific side of the field in critical moments of the game (Bartlett, Button, Robins, Dutt-Mazumder, & Kennedy, 2012).

Tactical behaviour analyses have been developed during competitive forms and using small-sided and conditioning games (SSCGs). It is due to the fact that SSCGs may have identical tactical problems and may contribute to the coaching processes (Serra-Olivares, González-Víllora, García-López, & Araújo, 2015). Thus, tactical behaviour analysis using SSCGs supports the teaching and coaching processes (Davids, Araújo, Correia, & Vilar, 2013; Serra-Olivares et al., 2016).

In regards to the modification of the field size, findings show that different playing areas alter the relative space per player, and it has an impact on performance behaviours (Casamichana & Castellano, 2010; Fradua et al., 2013). This results from the necessity of players and teams to adapt their tactical organization (Chow et al., 2006; Davids et al., 2013). For example, smaller playing areas decrease the relative space per player and teams constraining tactical organizations such as defensive stability and the creation of offensive opportunities (Travassos, Gonçalves, Marcelino, Monteiro, & Sampaio, 2014).

Different trajectories of the players and spatial distributions have been observed in SSCGs when the size of the pitch is altered (Silva et al., 2014). In this way, more advantageous numerical relations adjacent to each individual player and broader individual spatial distributions were observed when the field dimension is modified (Silva et al., 2016). Other studies have showed that in smaller field dimensions players and teams have fewer opportunities to maintain ball possession (Vilar et al., 2014), and in shorter dimensions different inter-team lateral and longitudinal distance values may be observed (Frencken, Van Der Plaats, Visscher, & Lemmink, 2013).

Despite of such evidences of tactical adjustments in smaller and conditioned formats, no studies have been analysing the effects of conditioned games (e.g., changing the size) in official format 11 vs. 11 on soccer, as far as we know. Such adaptation is commonly used by coaches in daily practice to increase the pressing in the team with possession of the ball and also to reduce the time to decision making time. In the foregoing, it is important to know the effects of the size modification on tactical behaviours by using new measures of tactical behaviour analysis. Therefore, the aim of this study was to analyze the variance of tactical behavior measured by the centroid and stretch index of the team between two different field sizes (full and half) in 11 vs. 11 format. We hypothesize that the centroid will stay in a forward position in the bigger field and a greater expansion of the team will be also observed.

Methods

Participants

A total of 10 Portuguese amateur soccer players from the same team (age = 23.39 ± 3.91 years old; body mass = 73.80 ± 5.62 kg; height: 178.96 ± 4.15 cm) participated in two 11 vs. 11 SSCG in different field sizes in the season 2016/2017. The goalkeepers participated in the games, but were excluded from the analysis. All the players were informed about the research procedures, requirements, benefits and risks, and their written consent was obtained before the study began. The experiment followed the recommendations of Declaration of Helsinki for the study in humans.

Procedures

The study was conducted in two different days spaced by a week. The 11 vs. 11 situations following the official rules were played in a full soccer pitch (108×68 m) and half field (54×68 m) during 30 minutes. The games were interspersed by one week. The day of data collecting corresponded in both situations to the day -3 before the weekend game. The experimental procedures occurred in the morning session (10.30 a.m.) with a temperature between 14 and 16º C and a relative humidity between 65 and 70%. Both games were played in the same natural turf. All the players followed a standard warm-up protocol of 20 minutes consisting of running, dynamic stretching, balance and ball possession drills. The coach distributed the players in two balanced teams based on technical skills, tactical proficiency and fitness level to ensure the stability of the analysis situations, as in previous studies (Gonçalves et al., 2014). Both formations comprised 1 goalkeeper, 4 defenders, 3 midfielders and 3 forwards (1-4-3-3) with the players assuming their positional roles.

Data collecting

Data position of 10 players of the same team were collected at 10 Hz using GPS units (10Hz, Accelerometer 1kHz, FieldWiz, Paudex, Switzerland) placed in a specific vest on the upper back of each player. The FieldWiz GPS trackers had demonstrated a good level of accuracy (<5%) for the measured total distance of the straight line and team sport simulation circuit protocols in an independent study (University of Brighton, School of Sport and Service Management, 2016). The reliability is also proper for scientific proposal considering that such did not have significant differences in any distance covered or speed between sessions in the same independent study (University of Brighton, School of Sport and Service Management, 2016). The raw position data was then extracted from the units and imported in the software Ultimate Performance Analysis Tool (uPATO) (Clemente, Silva, Martins, Kalamaras, & Mendes, 2016). The uPATO is a dedicated software to import position data and to compute specific tactical measures based on such bidimensional information. The uPATO it is not a commercial software and belongs to the Instituto de Telecomunicações, Covilhã, Portugal.

Positional variables

Two tactical measures were computed based on positional data: i) centroid; and ii) stretch index. Both variables were tracked for the same team in all moments of the game extracted by the GPS units. The average of centroid and stretch index for all periods (with and without possession of the ball, without differentiating both) were computed per periods of 30 seconds and then used in the statistical procedures. The aim of using both variables was to measure the geometrical center of the team and to quantify the expansion of the players during the games.

Centroid

The centroid of a team is the geometrical center of the polygon formed by the points representing the location of each player of the team, at a given instant (Bourbousson, Sève, & McGarry, 2010). To calculate the centroid, an average of the position of all the players of a team is calculated, for each instant. This calculation is presented formally in definition 1.

Definition 1 (Bourbousson et al., 2010)

The centroid of a team, for any given moment t, is given by the following equation:

$$C(t) = \left(\frac{\sum_i^N p_{xi}(t)}{N}, \frac{\sum_i^N p_{yi}(t)}{N} \right),$$

where N represents the number of players in the team, $p_{xi}(t)$ the position along the longitudinal axis for player i in instant t, and $p_{yi}(t)$ the position along the vertical axis for player i in instant t.

Figure 1 represents an example of centroid in a single instant of the match computed by uPATO software.

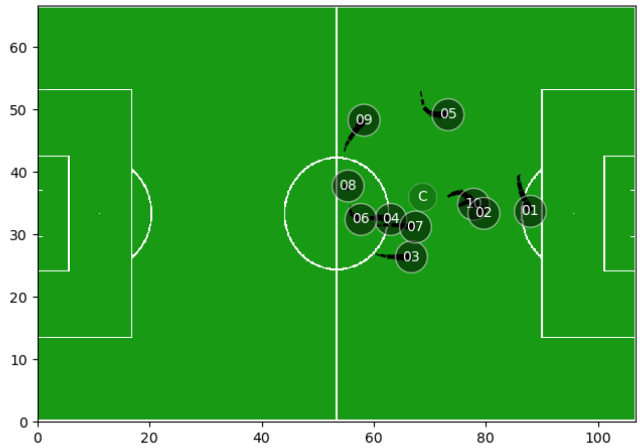

Figure 1. Example of centroid in a 11 vs. 11 format for one team (excluding goalkeeper). The circumference with 'c' represents the geometrical center of the team. Visualization obtained from uPATO software.

Stretch index

The stretch index measures the compactness of a team on a given moment. It is calculated by averaging the distances between each player to its team centroid (Silva, Vilar, Davids, Araújo, & Garganta, 2016). This is calculated both for the global positions, as well as specifically for the goal-to-goal and side-to-side directions separately. This calculation is presented formally in definitions 2, 3 and 4.

Definition 2 (Bourbousson et al., 2010)

The stretch index, considering both axes, at a given instant t can be calculated by:

$$SI(t) = \frac{\sum_i^N \sqrt{\left(P_{xi}(t) - C_x(t)\right)^2 + \left(P_{yi}(t) - C_y(t)\right)^2}}{N},$$

where C(t) represents the centroid of the team, N the number of players in the team, $P_{xi}(t)$ the position along the longitudinal axis for player i at instant t, and $P_{yi}(t)$ the position along the vertical axis for player i in instant t.

Definition 3 (Bourbousson et al., 2010)

The stretch index on a single axis, for a given instant t, is given by the following expression:

$$SI_x(t) = \sum_i^N |P_{xi}(t) - C_x(t)|,$$

where $C_x(t)$ represents the x coordinate for the centroid at instant t and $P_{xi}(t)$ the position along the longitudinal axis for player i at instant t.

Remark 1: The same formula is applicable for the calculation along the vertical axis, only replacing $P_{xi}(t)$ for $P_{yi}(t)$ and $C_x(t)$ for $C_y(t)$.To calculate the average values of the stretch index both for the coordinates along the two axes and for each axis separately, the following definition is used.

Definition 4

The average stretch index is given by the following equation:

$$SI = \frac{\sum_{t}^{N_t} SI\,(t)}{N_t},$$

where N_t represents the total number of time instants measured.

Remark 2: This same formula is applicable for SI_x and SI_y, by replacing SI(t) for $SI_x(t)$ or $SI_y(t)$, respectively.

An example of stretch index representation in uPATO software can be observed in the following Figure 2.

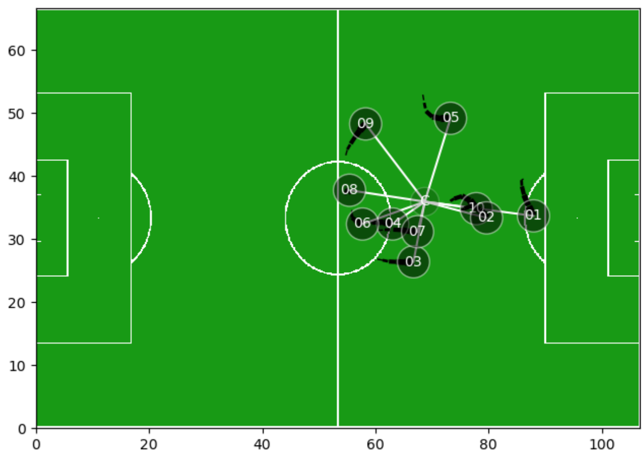

Figure 2. Stretch index of a team during 11 vs. 11 format (excluding goalkeepers). The white lines represent the distance from each player to the centroid. Visualization obtained from uPATO software.

Statistical procedures

The analysis of variance of centroid and stretch index between full and half fields was tested. After validation of normality and homogeneity of the data it was executed the independent t-test followed by the calculus of Cohen D to obtain the effect size (ES) of the test. The following classification to measure the magnitude of ES was used (Ferguson, 2009): no effect ($d < 0.41$), minimum effect ($0.41 < d < 1.15$), moderate effect ($1.15 < d < 2.70$) and strong effect ($d > 2.70$). The tests were executed using the SPSS software (version 23.0, USA) for a statistical significance at 5%.

Results

Analysis on the variance of the centroid (goal-to-goal and lateral-to-lateral) and stretch index (total, goal-to-goal and lateral-to-lateral) between pitch sizes was tested with independent t-test. Descriptive statistics can be found in table 1.

Table 1. Descriptive statistics (mean, standard deviation and 95% Confidence interval) of centroid and stretch index for both pitch sizes (half and full).

	C(*x*) (m) M±SD [95%CI]	C(*y*) (m) M±SD [95%CI]	SI*t* (m) M±SD [95%CI]	SI(*x*) (m) M±SD [95%CI]	SI(*y*) (m) M±SD [95%CI]
Half Size	24.50±8.38* [22.33-26.66]	33.07±6.07* [31.51-34.64]	35.53±9.53* [33.07-37.99]	18.27±8.96 [15.96-20.59]	13.44±7.83* [11.42-15.46]
Full Size	58.63±9.58* [56.16-61.11]	36.80±3.93* [35.79-37.82]	45.82±7.75* [43.82-47.82]	22.09±16.23 [17.89-26.28]	18.61±8.62* [16.38-20.84]
p	0.001	0.001	0.001	0.114	0.001
ES	3.794	0.729	1.185	0.291	0.628

*Significant different for a p < 0.005

C(*x*): centroid (goal-to-goal); C(*y*): centroid (lateral-to-lateral); SI*t*: Stretch index total; SI(*x*): Stretch index (goal-to-goal); SI(*y*): Stretch index (lateral-to-lateral); p: p-value; ES: Cohen D value.

Significant greater values of centroid (goal-to-goal) were found in the full size ($p = 0.001$; *ES* = 3.794, *strong effect*). Considering the middle of the pitch in both conditions, it is possible to verify that in half condition the mean of the centroid is 2.5 m (3.70% of the *x* size for the half pitch) behind the middle of the pitch and in the full condition it is 4.6 m (4.26% of the *x* size for the full pitch) beyond the middle of the pitch. Variation of the centroid throughout the time can be verified in Figure 3.

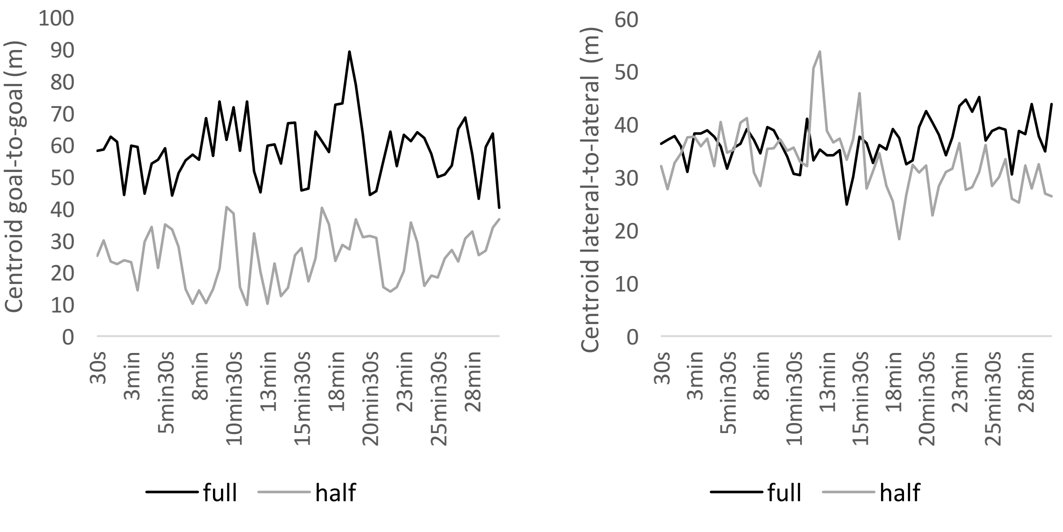

Figure 3. Centroid position (goal-to-goal and lateral-to-lateral) in both pitch sizes over the time.

Significant greater values of the centroid (lateral-to-lateral) were found in the full size ($p = 0.001$; *ES* = 0.729, *minimum effect*). In the half size condition, it was found that the average of centroid was 0.93 m (2.94% of the lateral-to-lateral half size) for the right side of the middle of the lateral-to-lateral and in the full size it was observed 2.8 m (4.12% of the lateral-to-lateral full size) for the left.

Significant greater values of total stretch index were observed in the full size ($p = 0.001$; $ES = 1.185$, *moderate effect*). As is possible to identify, the coefficient of variation of the total stretch index was 28.74% for the half size and 16.91% for the full size, thus suggesting a greater stabilization of this variable in bigger sizes. Values of the total stretch index during the matches can be observed in Figure 4.

Figure 4. Stretch index in both pitch sizes over the time.

Significant greater values of stretch index (lateral-to-lateral) were found in the full size ($p = 0.001$; $ES = 0.628$, *minimum effect*). A coefficient variation of 46.32% was found in the full size and 58.26% in the half size, suggesting a greater variation of lateral-to-lateral displacement in the half size. In the case of stretch index (goal-to-goal), no significant differences were found between pitch sizes ($p = 0.114$; $ES = 0.291$, *no effect*). A coefficient of variation of 73.47% was found in the full size and 49.04% in the half size, thus suggesting a greater dispersion of values in the full size.

Discussion

The size of the pitch is one of the key conditions utilized by coaches to constrain the collective behavior during training sessions (Davids et al., 2013). For that reason, this study aimed to analyze the spatio-temporal relationships between teammates in the official format of 11 vs. 11 in two different pitch scenarios: half size and full size. The main results revealed significant differences in centroid position and stretch index between the two analyzed situations.

The stretch index can be used to measure the dispersion of the players around the geometrical center based on the instantaneous position of players (Bartlett et al., 2012; Bourbousson et al., 2010). This measure has also been associated with collective patterns during attacking and defensive moments, representing the capacity of the team to play closer during defensive pressing and to expand while attacking (Clemente et al., 2013). In our study, it was found that there was a significant increase in stretch index (total) values in the case of full pitch. The average expansion of the team in the full size game was almost 29% (~10 m) more than in half pitch game, thus suggesting that the size of the pitch may constrain the way how dots (players) interact and rationally occupy the space. In a previous study, conducted in 4 vs. 4 format, it was found that the surface area (area of the polygon capable of contain all dots of a team, formed by the minimum amount of dots) was minimally affected by reducing width and length of the field considering a stabilization of interactive behavior (Frencken, van der Plaats, Visscher, & Lemmink, 2013). However, our stretch index in the goal-to-goal axis revealed no significant differences between pitch sizes, thus suggesting that the strategy of the team did not increase dispersion between sectors (length), but raised the dispersion in terms of the width. This can be a specific option of the team to attract opponents from the middle for the wingers to be able to exploit the possibility of unbalance in the defensive 'block' of the opponents. Our results only found significant differences in the lateral-to-lateral axis, thus suggesting the use of the option to spread the team through its wings. This option can be partially justified by the mobility principle that aims to unbalance the defensive organization of opponent through a fast shifting and good ball circulation (Gréhaigne, Richard, & Griffin, 2005).

The geometrical center of the team (centroid) in both axes was also analyzed in this study. The centroid represents the middle point of all the dots of a team and can provide information about the zone of balance of a team (Clemente et al., 2014a). In a study that compared the relationship between the teams' centroid, it was found that there is a strong association between the two teams in goal-to-goal and lateral-to-lateral axes and also that smaller pitches resulted in a closer relationship between the teams' centroid (Frencken et al., 2013). Our results revealed significant differences of the centroids between both pitch sizes. In the goal-to-goal direction of the centroid, it was found that, in average, the team occupied a region behind the middle line of the pitch in the half size, and a zone beyond in the full pitch. Our study did not consider the status of possession of the ball, and for that reason, it is possible to justify the region of centroid being close to the middle line of the pitch. However, these results were similar to previous studies that compared the centroid position in different status of possession of the ball and score (Clemente et al., 2013; Clemente, Couceiro, Martins, Mendes, & Figueiredo, 2014c). A tendency to occupy the right side in half size and the opposite side in the full pitch was observed in the case of lateral-to-lateral centroid. This may be constrained by the specific interactions that emerged from the game (Vilar, Araújo, Travassos, & Davids, 2014).

This study has some limitations. The absence of analysis of the possession of the ball reduces the analysis of the collective patterns due to not having data on the phase of the game. Moreover, future studies must consider the inter-teams distance (centroids) and the relationship between the centroids. Such analysis will improve the perception on how teams may be interactively constrained by the same variable.

Despite the limitations of the study, and to the best of our knowledge, this study was the first to analyze the influence of playing in a full size and half size in a 11 vs. 11 format, and one of the few studies that have analyzed the impact of the size of the pitch in the tactical behavior of teams measured by data position metrics. As practical implications, it can be possible to recommend using the full pitch size to increase the lateral-to-lateral space and to increase the space occupied by the team, thus being in line with the tactical principle of mobility. Future studies must consider extending such analysis to smaller formats of the game, different task conditions and to add more variables associated with the status of ball possession and spatio-temporal relationship between teams.

Conclusion

Results of this study revealed a greater lateral-to-lateral dispersion of the team in full size of pitch when compared to half size. Moreover, the centroid was beyond the middle line of the pitch in full size, and behind it in the half size. It is possible to conclude that the full pitch size promotes the adjustment of the team in order to spread to the wings and to be in line with the tactical principle of mobility. Half pitch can be more adequate to act proximally and to promote the principle of acting in unit. Future studies must consider the analysis of the spatio-temporal relationships between teams in different sizes and in other formats.

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References

Araújo, D.; Davids, K., & Hristoviski, R. (2006). The ecological of decision making in sport. *Psychology of Sport and Exercise*, *7*(6), 653-676. https://doi.org/10.1016/j.psychsport.2006.07.002

Aughey, R. J. (2011). Applications of GPS technologies to field sports. *International Journal of Sports Physiology and Performance*, *6*(3), 295–310. https://doi.org/10.1123/ijspp.6.3.295

Bartlett, R.; Button, C.; Robins, M.; Dutt-Mazumder, A., & Kennedy, G. (2012). Analysing team coordination patterns from player movement trajectories in football: Methodological considerations. *International Journal of Performance Analysis in Sport*, *12*(2), 398–424.

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. https://doi.org/10.1080/02640410903503640

Carling, C.; Williams, A. M., & Reilly, T. (2005). *Handbook of soccer match analysis: A systematic approach to improving performance*. Book, London & New York: Taylor & Francis Group. https://doi.org/10.4324/9780203448625

Casamichana, D., & Castellano, J. (2010). Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *Journal of Sports Sciences*, *28*(14), 1615–1623. https://doi.org/10.1080/02640414.2010.521168

Chow, J. Y.; Davids, K.; Button, C.; Shuttleworth, R.; Renshaw, I., & Araujo, D. (2006). Nonlinear pedagogy: a constraints-led framework for understanding emergence of game play and movement skills. *Nonlinear Dynamics, Psychology, and Life Sciences*, *10*(1), 71–103.

Clemente, F. M.; Couceiro, M. S.; Fernando, M. L.; Mendes, R., & Figueiredo, A. J. (2013). Measuring tactical behaviour using technological metrics: Case study of a football game. *International Journal of Sports Science & Coaching*, *8*(4), 723–739. https://doi.org/10.1260/1747-9541.8.4.723

Clemente, F. M.; Couceiro, M. S.; Martins, F. M. L.; Mendes, R., & Figueiredo, A. J. (2013). Measuring Collective Behaviour in Football Teams: Inspecting the impact of each half of the match on ball possession. *International Journal of Performance Analysis in Sport*, *13*(3), 678–689.

Clemente, F. M.; Couceiro, M. S.; Martins, F. M. L.; Mendes, R. S., & Figueiredo, A. J. (2014). Intelligent systems for analyzing soccer games: The weighted centroid. *Ingeniería E Investigación*, *34*(3), 70–75. https://doi.org/10.15446/ing.investig.v34n3.43602

Clemente, F. M.; Couceiro, M. S.; Martins, F. M. L.; Mendes, R. S., & Figueiredo, A. J. (2014). Practical implementation of computational tactical metrics for the football game: Towards an augmenting perception of coaches and sport analysts. In Murgante, Misra, Rocha, Torre, Falcão, Taniar, … Gervasi (Eds.), *Computational science and its applications* (pp. 712–727). Springer. https://doi.org/10.1007/978-3-319-09144-0_49

Clemente, F. M.; Couceiro, M. S.; Martins, F. M. L.; Mendes, R. S., & Figueiredo, A. J. (2014). Using collective metrics to inspect spatio-temporal relationships between football players. *South African Journal for Research in Sport, Physical Education and Recreation*, *36*(2), 47–59.

Clemente, F. M.; Silva, F.; Martins, F. M. L.; Kalamaras, D., & Mendes, R. S. (2016). Performance Analysis Tool for network analysis on team sports: A case study of FIFA Soccer World Cup 2014. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, *230*(3), 158–170. https://doi.org/10.1177/1754337115597335

Coutts, A. J. (2014). Evolution of football match analysis research. *Journal of Sports Sciences*, *32*(20), 1829–1830. https://doi.org/10.1080/02640414.2014.985450

Davids, K.; Araújo, D.; Correia, V., & Vilar, L. (2013). How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exercise and Sport Sciences Reviews*, *41*(3), 154–161. https://doi.org/10.1097/JES.0b013e318292f3ec

Davids, K.; Button, C.; Araújo, D.; Renshaw, I., & Hristovski, R. (2006). Movement models from sports provide representative task constraints for studying adaptive behavior in human movement systems. *International Society for Adaptive Behavior*, *14*(1), 73–95. https://doi.org/10.1177/105971230601400103

Di Salvo, V.; Baron, R.; Tschan, H.; Calderon, F. J.; Bachl, N., & Pigozzi, F. (2007). Performance characteristics according to playing position in elite soccer. *International Journal of Sports Medicine*, *28*, 222–227. https://doi.org/10.1055/s-2006-924294

Duarte, R.; Araújo, D.; Correia, V., & Davids, K. (2012). Sports teams as superorganisms: implications of sociobiological models of behaviour for research and practice in team sports performance analysis. *Sports Medicine*, *42*(8), 633–642. https://doi.org/10.1007/BF03262285

Duarte, R.; Araújo, D.; Folgado, H.; Esteves, P.; Marques, P., & Davids, K. (2013). Capturing complex, non-linear team behaviours during competitive football performance. *Journal of Systems Science and Complexity*, *26*(1), 62–72. https://doi.org/10.1007/s11424-013-2290-3

Ferguson, C. J. (2009). An effect size primer: A guide for clinicians and researchers. *Professional Psychology: Research and Practice*, *40*(5), 532–538. https://doi.org/10.1037/a0015808

Fradua, L.; Zubillaga, A.; Caro, O.; Fernández-García, A.; Ruiz-Ruiz, C., & Tenga, A. (2013). Designing small-sided games for training tactical aspects in soccer: extrapolating pitch sizes from full-size professional matches. *Journal of Sports Sciences*, *31*(6), 573–81. https://doi.org/10.1080/02640414.2012.746722

Frencken, W.; Lemmink, K.; Delleman, N., & Visscher, C. (2011). Oscillations of centroid position and surface area of football teams in small-sided games. *European Journal of Sport Science*, *11*(4), 215–223. https://doi.org/10.1080/17461391.2010.499967

Frencken, W.; Poel, H.; Visscher, C., & Lemmink, K. (2012). Variability of inter-team distances associated with match events in elite-standard soccer. *Journal of Sports Sciences*, *30*(12), 1207–13. https://doi.org/10.1080/02640414.2012.703783

Frencken, W.; Van Der Plaats, J.; Visscher, C., & Lemmink, K. (2013). Size matters: Pitch dimensions constrain interactive team behaviour in soccer. *Journal of Systems Science and Complexity*, *26*(1), 85–93. https://doi.org/10.1007/s11424-013-2284-1

Frencken, W.; van der Plaats, J.; Visscher, C., & Lemmink, K. (2013). Size matters: Pitch dimensions constrain interactive team behaviour in soccer. *Journal of Systems Science and Complexity*, *26*(1), 85–93. https://doi.org/10.1007/s11424-013-2284-1

Gómez-Ruano, M. Á. (2017). La importancia del análisis notacional como tópico emergente en Ciencias del deporte [The importance of performance analysis as an emergent research topic in sport sciences]. *RICYDE. Revista Internacional de Ciencias del Deporte*, *13*(47), 1-4. https://doi.org/10.5232/ricyde2017.047ed

Gonçalves, B. V.; Figueira, B. E.; Maçãs, V., & Sampaio, J. (2014). Effect of player position on movement behaviour, physical and physiological performances during an 11-a-side football game. *Journal of Sports Sciences*, *32*(2), 191–9. https://doi.org/10.1080/02640414.2013.816761

Gréhaigne, J. F.; Bouthier, D., & David, B. (1997). Dynamic-system analysis of opponent relationship in collective actions in football. *Journal of Sports Sciences*, *15*(2), 137–149. https://doi.org/10.1080/026404197367416

Gréhaigne, J. F.; Richard, J. F., & Griffin, L. (2005). *Teaching and learning team sports and games*. Book, New York, USA: Routledge Falmar.

Serra-Olivares, J.; Clemente, F. M., & González-Víllora, S. (2016). Tactical expertise assessment in youth football using representative tasks. *SpringerPlus*, *5*(1), 1301. https://doi.org/10.1186/s40064-016-2955-1

Serra-Olivares, J.; García-López, L. M., & Calderón, A. (2016). Game-Based Approaches, Pedagogical Principles and Tactical Constraints: Examining Games Modification. *Journal of Teaching in Physical Education*, *35*(3), 208–218. https://doi.org/10.1123/jtpe.2015-0125

Serra-Olivares, J.; González-Víllora, S.; García-López, L. M., & Araújo, D. (2015). Game-Based Approaches' Pedagogical Principles: Exploring task constraints in youth soccer. *Journal of Human Kinetics*, *46*(1), 251–261. https://doi.org/10.1515/hukin-2015-0053

Silva, P.; Chung, D.; Carvalho, T.; Cardoso, T.; Davids, K.; Araújo, D., & Garganta, J. (2016). Practice effects on intra-team synergies in football teams. *Human Movement Science*, *46*, 39–51. https://doi.org/10.1016/j.humov.2015.11.017

Silva, P.; Duarte, R.; Sampaio, J.; Aguiar, P.; Davids, K.; Araújo, D., & Garganta, J. (2014). Field dimension and skill level constrain team tactical behaviours in small-sided and conditioned games in football. *Journal of Sports Sciences*, *32*(20), 1888–1896. https://doi.org/10.1080/02640414.2014.961950

Silva, P.; Vilar, L.; Davids, K.; Araújo, D., & Garganta, J. (2016). Sports teams as complex adaptive systems: manipulating player numbers shapes behaviours during football small-sided games. *SpringerPlus*, *5*(1), 191. https://doi.org/10.1186/s40064-016-1813-5

Travassos, B.; Davids, K.; Araújo, D., & Esteves, P. T. (2013). Performance analysis in team sports : Advances from an Ecological Dynamics approach. *International Journal of Performance Analysis in Sport*, *13*(1), 83–95.

Travassos, B.; Gonçalves, B.; Marcelino, R.; Monteiro, R., & Sampaio, J. (2014). How perceiving additional targets modifies teams' tactical behavior during football small-sided games. *Human Movement Science*, *38*, 241–250. https://doi.org/10.1016/j.humov.2014.10.005

Vilar, L.; Araújo, D.; Davids, K.; Travassos, B.; Duarte, R., & Parreira, J. (2014). Interpersonal coordination tendencies supporting the creation/prevention of goal scoring opportunities in futsal. *European Journal of Sport Science*, *14*(1), 28–35. https://doi.org/10.1080/17461391.2012.725103

Vilar, L.; Araújo, D.; Travassos, B., & Davids, K. (2014). Coordination tendencies are shaped by attacker and defender interactions with the goal and the ball in futsal. *Human Movement Science*, *33*(1), 14–24. https://doi.org/10.1016/j.humov.2013.08.012