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The effects of large-sided soccer training games and pitch size manipulation on time–motion profile, spatial exploration and surface area: Tactical opportunities

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Abstract

Analysis of the physical, technical and physiological variations induced through the use of different soccer game formats have been widely discussed. However, the coaching justification for the specific use of certain game formats based on individual and collective spatial awareness is unclear. As a result, the purpose of this study was to analyze 11 versus 11 game formats conducted across two pitch sizes (half-size: 54 m × 68 m vs full-size: 108 m × 68 m) to identify effects of time–motion profiles, individual exploration behavior and collective organization. A total of 10 amateur soccer players from the same team (23.39 ± 3.91 years old) participated in this study. Data position of the players was used to calculate the spatial exploration index and the surface area. Distances covered in different speeds were used to observe the time–motion profile. The full-size pitch dimensions significantly contributed to greater distances covered via running (3.86–5.52 $m\,s^{-1}$) and sprinting (> 5.52 $m\,s^{-1}$). Total distance and number of sprints were also significantly greater in the full-size pitch as compared to the half-size pitch. The surface area covered by the team (half-size pitch: 431.83 m^2 vs full-size pitch: 589.14 m^2) was significantly larger in the full-size pitch condition. However, the reduced half-size pitch significantly contributed to a greater individual spatial exploration. Results of this study suggest that running and sprinting activities increase when large, full-size pitch dimensions are utilized. Smaller surface area half-size pitch contributes to a better exploration of the pitch measured by spatial exploration index while maintaining adequate surface area coverage by the team. In conclusion, the authors suggest that the small half-size pitch is more appropriate for low-intensity training sessions and field exploration for players in different positions. Alternatively, the large full-size pitch is more appropriate for greater physically demanding training sessions with players focused on positional tactical behavior.

Keywords

Geolocation, computational metrics, football, positional mapping, behavior, positional demands, pitch size, soccer tactical

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Introduction

Recent literature in the development of soccer training has concentrated on the effects of training game modifications and their effects on key variables that influence the physical, physiological and/or tactical demands imposed upon the players.[1–3] Previous work has highlighted a thorough understanding of the use of various sided-training games[4,5] and small-sided conditioned games (SSCG) for teaching–coaching purposes.[6] Analysis of physical and physiological differences, depending on the game format, have been conducted in

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order to develop a clearer picture of player demands,[5,7,8] whereas additional research has focused attention on decision-making skills and SSCG that may exaggerate tactical obstacles.[9,10]

However, research is very limited in this topic resulting in uncertainty in predicting the key modifications needed to maximize strategies for teaching and coaching tactical awareness. As a result, analysis of various game modifications and their effects on physical, physiological and tactical variables is required in order to further identify best coaching practices.

To assist in further investigations surrounding this topic, modern methods such as the use of global positional systems (GPS) contribute significantly to the establishment of a solid knowledge base concerning the use of SSCG for improving physical–physiological demands[5,11] and also for the tactical coaching behavior.[12–14] Differences in physical and physiological variables have been observed when pitch size is varied.[5,7] Activity profiles of players have been analyzed for different pitch sizes; however, results are not consistent.[3,8,15,16] Thus, a systematic review of the different pitch size modification effects on physical and physiological demands is necessary[17] while taking into account the importance of physical demands on tactical behaviors.[18]

According to previous literature, when pitch sizes are significantly altered, the change impacts performance in tactical behaviors.[3,19] Differences in pitch dimensions may also constraint the intra-team synchronization.[20] Teams training within small-sided game (SSG) formats tend to have issues with organization from a tactical perspective, such as the stability in the defensive behavior and the transitional creation of offensive opportunities when attacking.[21] When pitch sizes are reduced, smaller team sizes and limited ball possession options cause issues in possession retention.[22] This may be as a result of less time per ball possession and increased pressure of opposition due to smaller surface area per player, leading to reduced decision-making process time.

Collective team play, positional units and individual players adjust their movement trajectory, which in turn affects their spatial distribution throughout the course of training or competitive match play. The playing surface area or pitch size significantly affects decision-making and movement profiles. As a result, specific tactical outcomes may therefore not be transferable to match related contexts due to the different area sizes and coaching methodology employed within the SSCG used.[23] Consequently, from a coaching perspective, determining which surface area or pitch size would lend itself to an improved teaching–training objective remains unclear. Generally, training in environments similar to those encountered in competition would be proposed. However, coaches do not always have enough players to recreate these competition scenarios. To the best of the current author's knowledge, no studies have been performed analyzing the effects of manipulating pitch dimensions of large-sided 11 versus 11 training games. These adjustments are often used by coaches in daily practice to create pressure for the players during attacking phases and augment the optimization of collective behavior. However, the effects of such task constraints on time–motion profile and collective organization of players must be known. For that reason, the purpose of this study was to analyze the effects of two different pitch sizes (large full-size 108 m × 68 m and small half-size 54 m × 68 m) on the time–motion profile of the players, individual spatial exploration and collective spatio-temporal organization measured by the surface area.

Methods

Participants

A total of 10 amateur soccer players from the same team age 23.39 ± 3.91 years old, weighing 73.80 ± 5.62 kg with heights 178.96 ± 4.15 cm participated voluntarily in this study. The data collection occurred in the middle of the 2016/2017 season. Goalkeepers were excluded from the data acquisition. Players were informed about the experimental protocol, inclusion criteria, benefits and risks. All players were required to sign a written consent form. The experimental approach was conducted following the ethical standards for the study in humans as proposed by the Declaration of Helsinki.

Experimental approach

For this study, games for 11 versus 11 teams were played on two pitch sizes: half-size (54 m × 68 m) and full-size (108 m × 68 m). Both games lasted 30 min and were played a week apart. The rules were the same as those used in official games. The two games were played 2 days after and 3 days before official matches. Players complied to a 20-min warm-up protocol consisting of light-to-moderate running, dynamic stretching, mobility, fast running and ball possession drills. Games were played on the same natural turf. Temperatures ranged between 14°C and 16°C with a relative humidity between 65% and 70%. Players were distributed based on their regular positional role. The analyzed team assumed a 1-4-3-3 formation with one goalkeeper (excluded from the analysis), two external defenders, two central defenders, three midfielders, two wings and one striker.

Procedures of data collection

In order to collect position data, players were equipped with a 10-Hz GPS unit (10 Hz, Accelerometer 1 kHz, FieldWiz, Paudex, Switzerland) during both games. The GPS unit was placed on the upper back of the players to maximize the signal reception/transmission. After each game, the raw position data for the x and y

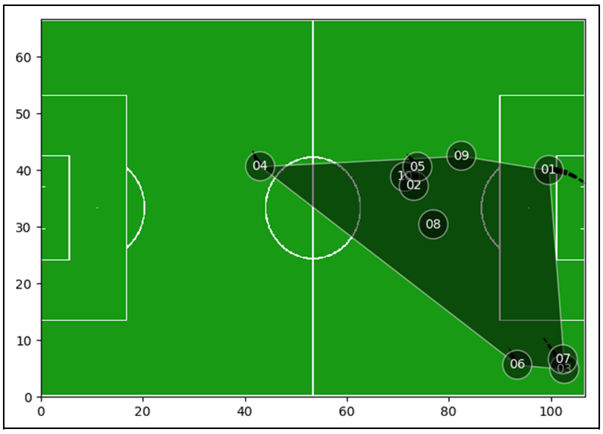

Figure 1. Representation of the surface area and players in the 11 versus 11 match for one team (excluding the goalkeeper), obtained from uPATO software.

positions from each player was uploaded. The raw data was then imported into the Ultimate Performance Analysis Tool (uPATO).[24] The uPATO is a software developed by Instituto de Telecomunicações (Covilhã, Portugal) to import data position and adjacency matrices while computing several collective and individual measures of sport performance.

Time–motion profile

The total distance covered by a top-level player is typically between 10 and 13 km, with most of the distance covered during low-intensity activities, with only 10% accrued during high-intensity activity.[25] An analysis on the distances covered by players show that top players execute more high-intensity activities than those at a lower level,[26] thus providing a metric for performance analysis of players. The distance was divided into four categories: (1) sprint when the speed rose above $5.52\,\mathrm{m\,s^{-1}}$, (2) run for speeds between 5.52 and $3.86\,\mathrm{m\,s^{-1}}$, (3) jog for speeds between 3.86 and $1.91\,\mathrm{m\,s^{-1}}$ and (4) walk for speeds less than $1.91\,\mathrm{m\,s^{-1}}$.

Spatial exploration index

The spatial exploration index allows one to measure the difference in pitch exploration between players. A higher index value represents better field coverage by the player.

The spatial exploration index of a player is given by equation (1)[27]

$$SEI = \frac{\Sigma_i^N \sqrt{(x_i - x_m)^2 + (y_i - y_m)^2}}{N} \tag{1}$$

where N represents the number of time instants for which the spatial exploration index was calculated and (x_m, y_m) the mean position of the player over the time period.

Surface area

The surface area of a team defines the space occupied by a team in a given instant. The surface area is calculated through the area of the convex hull, which is, in turn, calculated through the positions of all players of a team in a given instant. This was done with recourse to the Quickhull algorithm.[28]

Given a set of points, the following algorithm is applied:

```
Create a simplex of d + 1 points
For each facet F
  for each unassigned point p
    if p is above F
      assign p to F's outside set
For each facet F with a non-empty outside set
  select the furthest point p of F's outside set
  initialize the visible set V to F
  for all unvisited neighbors N of facets in V
    if p is above N
      add N to V
  the set of horizon ridges H is the boundary of V
  for each ridge R in H
    create a new facet from R and p
    link the new facet to its neighbors
  for each new facet F'
    for each unassigned point q in an outside set of a facet in V
      if q is above F'
        assign q to F''s outside set
  delete the facets in V.
```

From this algorithm, the convex hull of the team is created. The surface area is given by the area of the convex hull, in this case, a 2d area. From the coordinates of the vertices of the convex hull, the area can be calculated.

The surface area, given the coordinates of the vertices of the convex hull, is given by equation (2)[29]

$$SA = \frac{1}{2}\sum_{i=0}^{n-1} (x_i y_{i+1} - x_{i+1} y_i) \tag{2}$$

where n is the number of vertices of the convex hull.

An example representation of the surface area is presented in Figure 1 for the 11 versus 11 match, computed using uPATO software.

Statistical procedures

The independent t-test was used to analyze the variance of time–motion profile and spatial exploration index between pitch sizes (half and full). A mixed repeated measure was executed to analyze the variance of surface area between both size conditions during 5-min intervals. Assumptions of normality and homogeneity of the tests were verified. The effect size (ES) of the independent t-test was calculated with the Cohen D (d).[30] The following classification of magnitude of d was used:[31] no effect ($d < 0.41$), minimum effect ($0.41 < d < 1.15$), moderate effect ($1.15 < d < 2.70$)

Table 1. Descriptive statistics (mean ± standard deviation) of time–motion and spatial exploration index for both pitch conditions.

	Half-size pitch(M ± SD)	Full-size pitch(M ± SD)	D^a
Walking distance (m)	1171.17 ± 90.53	1204.67 ± 130.56	0.305
Jogging distance (m)	898.43 ± 191.60	1072.71 ± 240.45	0.813
Running distance (m)	347.99 ± 109.66*	603.12 ± 157.12*	1.925
Sprinting distance (m)	93.63 ± 43.45*	256.15 ± 76.23*	2.707
Total distance (m)	2511.23 ± 279.76*	3136.65 ± 323.80*	2.086
Sprints (n)	52.10 ± 24.38*	93.25 ± 19.04*	1.853
Spatial exploration index (%)	85.04 ± 1.63*	68.55 ± 9.23*	2.649

SD: standard deviation.
[a]*d*: Cohen *D* used to calculate effect size of the independent *t*-test.
*Significant difference at $p < 0.05$.

and strong effect ($d > 2.70$). The partial eta squared (η^2) has tested the ES on the repeated measures. The Ferguson's classification for the η^2 was used as follows:[31] no effect ($\eta^2 < 0.04$), minimum effect ($0.04 < \eta^2 < 0.25$), moderate effect ($0.25 < \eta^2 < 0.64$) and strong effect ($\eta^2 > 0.64$). Statistics were performed in the SPSS software (version 23.0, USA) for a statistical significance at 5%.

Results

The independent *t*-test revealed significant statistical differences between pitch sizes in the variables of running distance ($t = 0.001$; $d = 1.925$), sprinting distance ($t = 0.001$; $d = 2.707$), total distance ($t = 0.001$; $d = 2.086$), number of sprints ($t = 0.001$; $d = 1.853$) and spatial exploration index ($t = 0.001$; $d = 2.649$). Particularly, significant greater values of running distance, sprinting distance, total distance, number of sprints and maximum speed were observed in the full-size pitch condition. On the other hand, the spatial exploration index was significantly greater in the half-size pitch condition. No significant differences were found in the variables of walking distance ($t = 0.529$; $d = 0.305$) and jogging distance ($t = 0.106$; $d = 0.813$). Descriptive statistics of time–motion and spatial exploration index can be found in Table 1.

Mixed repeated measures did not show significant differences of surface area covered during a given game over time ($p = 0.206$; $\eta^2 = 0.374$, *moderate effect*) in both pitch sizes. However, significant differences in area covered were found between pitch sizes ($p = 0.001$; $\eta^2 = 0.638$, *strong effect*). Significant greater values of surface area covered were found in the full-size pitch. Mean and standard deviation throughout the periods of time for both pitch sizes can be found in Figure 2.

Discussion

Task constraints may influence tactical behavior and collective organization of soccer players. Based on that assumption, this study aimed to analyze the variance of time–motion profile and team's dispersion during two playing conditions: small half-size and large full-size pitches. Data position of the players (dots) were tracked and processed in the ultimate Performance Analysis Tool. Preliminary studies revealed that players covered more distance during moderate-to-high intensity speeds on the full-size pitch. Conversely, spatial exploration was significantly higher on the half-size pitch. In a collective perspective, significant greater values of surface area (polygon created by all players) were realized in the full-size game.

Time–motion profiles have been well researched during match activities.[32] A comparative study between small, medium and large pitch in the format of 4 versus 4 games revealed that significantly higher values of distance covered, high-speed distance, total acceleration, low-to-moderate acceleration, total deceleration and low-to-high deceleration were observed in the large pitch.[33] Similar evidence was found in a 5 versus 5 format where total distance, distance covered per minute and low-to-moderate running distance were significantly greater in the large pitch.[3] In corroboration with these findings, this study revealed significant greater values of running and sprinting distances, total distance, number of sprints and maximum speed in the full-size pitch.

Some possibilities may contribute to explain the results found in this study. In the study conducted in the 5 versus 5 format, the work-to-rest ratio between small and larger sizes was analyzed.[3] In that study, results revealed that the lowest work-to-rest ratio was found in the smaller pitch. This suggests that the larger pitch contributes to a more continuous activity while the smaller pitch may induce very high speed, intermittent activities that are interspersed by periods of recovery likely due to the inability to maintain such intensities.[3] Players may also become more aware of their tactical responsibilities in larger surface areas and therefore will take a better position in the larger games, based on results of spatial exploration index in this study. Small pitches may increase the variability and reduce the tactical awareness; however, more research is needed in this area.

The size of the pitch may also contribute to the activity profile of players. Larger pitches may provide the opportunity to cover longer distances, especially to explore the longitudinal axis. The higher interpersonal distances in the larger pitch[20] may also contribute to increased distance covered to reach a desired field location and opponents. The type of passes the opposition make in large-sided games may also contribute to the activity profile in the large pitch. In a larger area, more

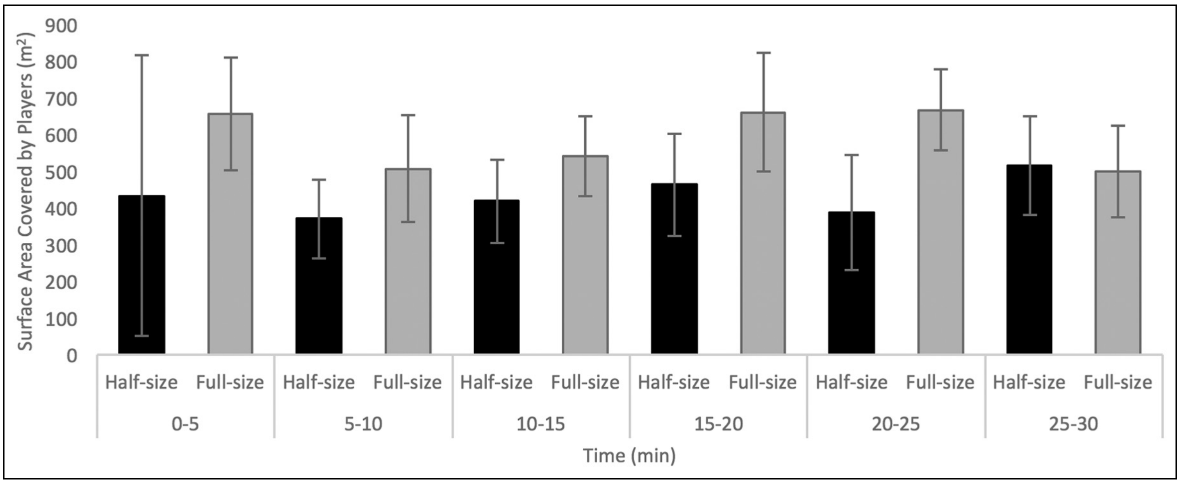

Figure 2. Surface area covered by players for both pitch sizes.

horizontal passing is likely to cause the opposing team to move, thus opening up space to penetrate passes. The authors suggest using notational analysis in future works to confirm such a hypothesis.

Individual tactical behavior was also analyzed in this study using the spatial exploration index. Results revealed significant greater values of exploration in the half-size pitch condition. A previous study used the spatial exploration index to measure the variance of players in different task conditions.[27] Higher values of this measure are associated with players covering more space during games. In this case, the half-size pitch will contribute to an increase in the spatial exploration index since the space to be covered is smaller, allowing the players to possibly exploit more zones around their positional area.

The way the dots, which represent players, connected during the game was also analyzed. The surface area was chosen to observe the dispersion of players in both full- and half-size pitch conditions. A previous study that tested the influence of four pitch sizes in a 4 versus 4 format revealed that the surface area covered did not change significantly.[20] The results from this study revealed significant greater values of area covered by the team in the full-size condition. However, the surface area covered on the full-size pitch, which was 100% larger than the half-size pitch, was only 36% greater than the area covered in the half-size pitch. In the study conducted in the 4 versus 4 format, teams occupied a similar playing area with the decrease in pitch size.[20] The results revealed that the increase in surface area from half to full-size condition was significant.

This study had some limitations. The sample was reduced and the results cannot be generalized. However, preliminary findings may allow future comparisons with other teams. Moreover, the acceleration and deceleration were not obtained. This would be beneficial to fully understand the effects in external load. This study determined that the number of sprints was significantly greater in the full-size condition, thus providing some information to manage the effort and the physical impact of the activities of the players.

Some practical implications can be addressed from this study. Half-size pitches seem applicable to a specified condition to exploit the space and manage the physical impact on the players. The physical load is lower and the tactical behavior can be ensured by an exploration of the space and the consolidation of collective behavior measured by the interaction between dots. On the other hand, full-size pitches increase the physical load and reduce the exploration of the pitch, thus contributing to a more positional participation in the game. Future studies must consider increasing the sample size and extending the comparison to other formats used by coaches in daily practice.

Conclusion

Results of this study suggested that the full-size pitch condition in an 11 versus 11 format significantly increased the physical impact of players including total distance, running and sprinting distances and number of sprints as well as the surface area covered by the players. The half-size pitch condition significantly contributed to a greater spatial exploration by the players. These findings confirm that the pitch size contributes to changes in time–motion profile, tactical behavior and collective organization, thus acting as an important condition for coaches to consider during daily practice.

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