Effects of pitch size and skill level on tactical behaviours of Association Football players during small-sided and conditioned games

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Effects of Pitch Size and Skill Level on Tactical Behaviours of Association Football Players During Small-Sided and Conditioned Games

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ABSTRACT

In Association Football, the study of variability in players' movement trajectories during performance can provide insights on tactical behaviours. This study aimed to analyse the movement variability present in: i) the players' actions zones and ii), distances travelled over time, considered as a player's positional spatial reference. Additionally, we investigated whether the movement variability characteristics of players from different skill levels varied. Two groups of U-17 yrs players of different performance levels (national and regional) performed in three small-sided games with varying pitch dimensions (small, intermediate and large). Linear and non-linear analyses were used to capture the magnitude and structure of their movement variability. Results showed that increases in pitch size resulted in more restricted action zones and higher distance values from personal spatial positional references for both groups. National-level players were more sensitive to pitch modifications and displayed more variability than regional-level players in the small and intermediate pitches. These findings advance understanding about individual tactical behaviours in Association Football and have implications for training design, using pitch size manipulation.

Key words: Movement Variability, Personal Locus, Spatial Distribution Maps, Task Constraints

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INTRODUCTION

In Association Football, analysis and interpretation of individual movement has focused on the players' time-motion characteristics by positional role during competitive match performance or during small-sided and conditioned training games (SSCGs), both receiving a considerable amount of attention [1-3]. Through this type of analysis, players' physical and physiological profiles have been investigated, providing an important body of knowledge for fitness training. However, strict time-motion analyses provide little information about players' tactical behaviours if they do not consider time-evolving spatial movement trajectories of players during performance.

In human behaviour, variability and nonlinear transitions in movements over time are essential for adaptive flexibility needed under ever-changing constraints of dynamic performance environments [4-7]. A dynamical systems approach proposes the view that coordination variability provides the system with the required flexibility to adapt to perturbations [4, 8]. From this perspective, movement variability is not viewed as error or noise [9-11], but reflects the adaptability of a performer-environment system usually associated with high levels of skill [5, 8]. It has been shown that a decrease or increase in movement variability can make a neurobiological system more rigid or unstable, respectively, and thus, less adaptable to perturbations [6-8].

In this context, the study of individual movement variability can explain how individuals performing in complex, dynamic environments, like team games, can manage space and time as a function of specific ecological constraints [12, 13].

For instance, Fonseca et al. [14] showed that ball possession impacted on individual movement behaviours in Futsal (indoor football). The attackers' dominant performance regions (constructed from Voronoi cells and representing the specific area allocated to each player in the field) were more variable in size among players of the same team, but displayed more regular sizes than those of defenders, which reflected the performance demands on behaviours of attacking and defending in futsal.

Other studies have recorded the players' predominant action zones [15, 16] and oscillatory movements around a specific performance locus on field [17, 18] as relevant concepts to quantify individual movements during performance from a tactical perspective. Analysis of movement variability associated with the spatial-temporal characteristics of such concepts may provide important information about individual playing behaviours by reflecting the presence of underlying organisational structures in players' movement patterns. By estimating the variability of players' action zones, one can understand whether play was more or less structured. If players travel through more variable zones on a performance field, it signifies that they are constrained to assume more broad tactical roles (e.g., moving both backwards – defending – and forward – attacking – or on left and right flanks). On the other hand, if players restrict their action zones to specific locations on field, then it can be interpreted as a more structured game, played according to specific positions and roles (e.g., left defender, striker, etc., see [19]).

Movements displayed by a player around a specific geometrical centre, or locus on field, can also provide information on important individual tactical behaviours. The locus represents the player's spatial positional reference around which he/she oscillates [18]. Through the assessment of the variability associated with these oscillatory movements it can be inferred how players manage space and time to converge towards and away from their spatial references during the game. The regularity, to which they are attracted to their locus, may be informative about players' awareness of their positional reference on field.

The importance of specific positioning and tactical roles has been considered, for instance, by developmental programmes in junior football, with coaching manuals usually advocating freedom of expression at early ages of practice and evolution into specific positions as players progress from smaller to bigger game formats [20]. It has been proposed that small-sided and conditioned games (SSCGs) require players to undertake offensive and defensive roles, while bigger game formats restrict players to specific defending, midfield and attacking positional roles [19]. There exists little firm evidence for this proposal.

Previous research on SSCGs in football, involving pitch size manipulations, has mainly focused on physical and technical characteristics of performance [21-23]. The only known study in Association Football that addressed performance in SSCGs with varying pitch dimensions *from a tactical perspective* showed that shorter and narrower pitches resulted in smaller longitudinal and lateral inter-team distance values, respectively, whereas a team's surface area decreased as a result of smaller total playing areas [24]. This study focused on the interpersonal relations between players and how they were constrained to adapt their interactive behaviour according to specific pitch size constraints. More studies are needed to understand how pitch size manipulations constrain individual tactical behaviour underlying collective performance in SSCGs. One way to gain this knowledge is through the analysis of the players' movement variability.

Additionally, an understanding of how players' skill levels may influence their adaptation to such constraints could provide valuable information about how individual characteristics impact on performance [25, 26]. Many practitioners and performers have been considering stability and consistency in movement, as well as compensatory movement variability to be essential characteristics of skilled performance [7, 27, 28]. Despite the relevance of spatial-temporal characteristics in football, the extent to which individual movement variability in football SSCGs and/or regular matches is a characteristic of more skilled performers has yet to be demonstrated.

Therefore, the purposes of the present study were twofold. First, we aimed to characterize the individual tactical behaviour of youth football players on SSCGs varying in pitch dimensions, through the analysis of spatial-temporal variability associated to their action zones and movement oscillations around the personal locus. A second aim was to investigate whether the movement variability characteristics of players from different skill levels were varied. We hypothesized that both pitch dimension and skill level would constrain players' movements, with more skilled players presenting higher values of movement variability than their less skilled counterparts across all pitch conditions.

METHODS

PARTICIPANTS

Two clubs participated in this research study, allowing data collection with ten U-17 youth male football players (n=20). The skill level was set based on competitive performance level. Players from Club A (aged 16.20±0.63 years old) competed at a national-level. Players from Club B (aged 15.60±0.52 years old) competed in the 2nd division of their district competition. Based on these criteria, participants were classified at national-level (NLP) or regional-level (RLP) of performance. All participants possessed more than six years of playing experience at their respective levels (NLP: 6.6±1.65 years; RLP: 6.2±2.35).

EXPERIMENTAL DESIGN

Each group of players was assigned to two teams by their respective coaches to ensure a balanced competitive game. Each team was composed of one goalkeeper, one defender, two midfielders and one striker, all of them specializing in these performance roles for more than three years. Both groups performed in three SSCGs of 7 minutes duration interspersed with 7 minutes resting periods to minimize the influence of fatigue on participants (exercise-rest ratio of 1:1)[1].

The SSCGs consisted of games of 4-a-side plus goalkeepers using 7-a-side goals. The goalkeepers played inside an area marked five-meters from the goal line and extending across the pitch width. Passing the ball to the goalkeeper was not allowed. All SSCGs were played accordingly to the remaining official rules of Association Football with the exception of the offside rule that was not applied.

During the SSCGs and rest periods, coaches did not provide any instructions, feedback or encouragement to the players. Several balls were placed around the pitches so that players could restart matches quickly when balls left the field of play. During recovery periods, participants were allowed to recover actively at will through low intensity activities. Common activities involved stretching, playing short passes between pairs and rehydration.

Pitch dimensions were calculated using the measures of an official football field – 105 x 68 m as a reference. The length and width were then reduced in proportion to the number of players involved in the SSCGs, as suggested in coaching literature [29]. The percentage of players involved in each SSCG was 45% (10 out of 22 players), and 45% of the official length and width corresponded to the intermediate pitch length and width. For small and large pitches, 10% was subtracted and added to the initial value of 45%, respectively (Table 1). The same ratio of 1.5:1 was maintained between length and width in all three pitches.

Table 1. Pitch dimensions. Percentages represent the proportion of official width and length measures (105 x 68 m).

	Small pitch (35%)	**Intermediate pitch (45%)**	**Large pitch (55%)**
Width	23.8 m	30.6 m	37.4 m
Length	36.8 m	47.3 m	57.8 m
Individual playing area	≈ 88 m^2	≈ 145 m^2	≈ 216 m^2

Both groups of participants played in the smallest pitch first, then the intermediate and ended with the largest pitch. The order of the SSCGs was set arbitrarily.

This protocol was operationalized prior to the clubs' regular training sessions (both teams used to practice in the late afternoon) in the middle of the week (i.e., equally distant from the last and the next official team competitive fixture). The players were informed that they would not participate in that day's training session after the completion of the experiment.

All players were familiarized with the practice of different SSCGs formats experienced since they had begun to play football.

[1] All players wore vests that contained heart rate monitors. The Edwards' training load (ETL) and the total distance travelled (TDT) per player were calculated to analyse any possible effects of fatigue on the experimental outcomes. As expected, the training load analysis yielded a greater physiological impact in the RLP in all SSCGs, albeit without significant differences between groups ($p=0.820$, $\eta^2=0.01$). There was also a considerable difference between NLP and RLP in the TDT per player in each pitch condition ($p<0.001$, $\eta^2=0.58$), with the greatest difference being noted on the large pitch, where the RLP have covered, on average, over 100 meters more than the NLP. It is unlikely that the less skilled players could have had a greater physiological impact on the last SSCG bout and yet still ran for greater distances than participants in the skilled group. In this sense, it seems that this outcome was due to tactical adaptations of each group to the specific task constraints and not due to fatigue.

DATA COLLECTION

Each player carried a global positioning tracking device (SPI Pro, GPSports, Canberra, Australia) that recorded longitudinal and latitudinal movement coordinates with a sampling frequency rate of 15Hz.

All pitches were calibrated with the coordinates of four GPS devices that were stationed in each corner of the pitch for about 2 minutes. The absolute coordinates of each corner were calculated as the median of the recorded time series, providing measurements that were robust to the typical fluctuations of the GPS signals. These absolute positions were used to set the Cartesian coordinate systems for each pitch, with the origin placed at the pitch centre. Longitudinal and latitudinal (spherical) coordinates were converted to Euclidean (planar) coordinates using the Haversine formula [30]. Fluctuations in the players' positions were reduced using a moving average filter with a time scale of 0.2 seconds and data resampling was employed to synchronize the time series of all players within each game.

DATA ANALYSIS

In this study, linear and non-linear analyses were used to examine the variability of the players' spatial-temporal characteristics. Linear tools used involved the percentage of coefficient of variation (CV) to quantify the overall variability. CV was complemented with non-linear methods that are paramount to describe the structure of variability [8, 31]. It involved two specific measures of entropy – Shannon and sample entropies.

Therefore, Shannon entropy [32] measures of individual spatial distribution maps were used to assess the underlying variability of the players' spatial distribution, providing a value that quantifies the uncertainty of locating each player in a specific location of the pitch (goalkeepers excluded). To calculate the spatial distribution maps, the pitch was discretized into bins and the amount of time spent in each bin was measured, according to the sampling frequency of the GPS acquisition system. The spatial distribution maps were normalized to total match time, to produce spatial probability distributions (2D). The size of the bins was the same for all pitches, chosen to satisfy an adequate balance between high spatial resolution and high range of measured values. A bin size of $1m^2$ was used allowing both sufficient spatial detail and large variability in the bin counting (>100×dt).

Considering a pitch partition with N bins and setting p_i as the measured probability of finding the player in bin i, the entropy S of the spatial distribution is

$$S = -\sum_{i=1}^{N} pi \log pi \tag{1}$$

Normalized entropy was used to place the results within the range between 0 and 1.

$$S\% = -\sum_{i=1}^{N} pi \log pi / \log N \tag{2}$$

A low Shannon entropy (ShannEn) value (near 0) indicates that the distribution is sharply peaked and the player's position can be easily predicted. A high ShannEn value (near 1) indicates that the distribution is uniform thus the player's position is highly variable and unpredictable. High and low ShannEn values were interpreted as high and low spatial distribution variability, respectively.

To analyse the time-evolving structure of the players' movement variability, an individual locus was assigned to each player and the instantaneous distances to this locus were calculated for each time point. The locus was defined as the median point (2D) of their motion trajectory due to the non-parametric distribution of data. The distance to the locus (L) time series was computed for each player (P) using the Pythagoras theorem - $D_{(L,P)}=\sqrt{((Lx - Px) + (Ly - Py))^2}$.

Linear analyses of the time series were performed to analyse the *magnitude* of the variability using the mean (M), standard deviation (SD) and percentage of coefficient of variation (CV) parameters.

Non-linear analyses were used to assess the *structure* of the variability of the signals using sample entropy measures (SampEn). SampEn(*m, r, N*) is defined as the negative natural logarithm of the conditional probability that two sequences similar for *m* points (length of the vector to be compared) remain similar at the next point $m + 1$ [33]. The similarity criterion is set by $r\times$SD of the time-series. The parameter combination used in this study was $m = 3$ and $r = 0.1$ (see appendix for details on parameters choice).

All player-to-locus distances (PLdt) time series were down-sampled to avoid local stationarities in SampEn calculation, which can ultimately lead to a decrease in entropy due to an increase in the number of matches of the template pattern [34]. Median PLdt velocity and acceleration for all sixteen players in all pitches were below 1m/s and $1m/s^2$, respectively. Therefore, a sampling rate of 1Hz was considered reasonable to capture PLdt time-variations under any pitch and skill conditions (N=420 data points, each point corresponding to 1-s).

SampEn values range from 0 towards infinity, where 0 represents a perfectly repeatable time series and infinity is a totally unpredictable time series. From this measure it can be inferred whether players displayed highly regular (i.e, periodical) (low SampEn) or highly irregular (high SampEn) PLdt.

Both spatial distribution maps and PLdt time series were calculated using MATLAB routines (R2011a, Mathworks, USA).

STATISTICAL PROCEDURES

ShannEn, PLdt, CV and SampEn were subjected to a mixed design split-plot ANOVA with a repeated measures (RM) design for pitch dimensions (3) and a between-groups effect for skill level (2). Effect sizes were reported as partial eta squared (η^2) and significant results were followed up with Bonferroni's pairwise comparisons. Greenhouse-Geisser adjustments were applied to violations of the sphericity assumption for the RM variable. The value of α was set at p=0.05.

All statistical analyses were conducted in SPSS 20.0 (SPSS Inc., Chicago, USA).

RESULTS

SPATIAL DISTRIBUTION VARIABILITY

In both groups, ShannEn values decreased as pitch dimension increased (Figure 1, top left panel). ANOVAs yielded a main effect for pitch dimension ($F=37.57$, $p<0.001$, $\eta^2=0.73$) and an interaction effect between pitch dimension and skill level ($F=6.99$, $p=0.003$, $\eta^2=0.33$).

Post-hoc analysis revealed significant differences between all pitches for the NLP ($p<0.001$ in all comparisons). The RLP presented significant differences between the small and the intermediate pitches (p=0.002), but not between the intermediate and the large pitches (p=0.71). Also, significant differences in ShannEn values were observed between NLP and RLP according to pitch dimensions. The NLP presented significantly higher values of ShannEn on small and intermediate pitches (p=0.01 and p=0.004, respectively), but not on the large pitch (p=0.59).

Figure 2 presents exemplar spatial distribution maps of two players from each group for each pitch dimension, highlighting higher variability in spatial distributions for the national-level players on the small and intermediate pitches.

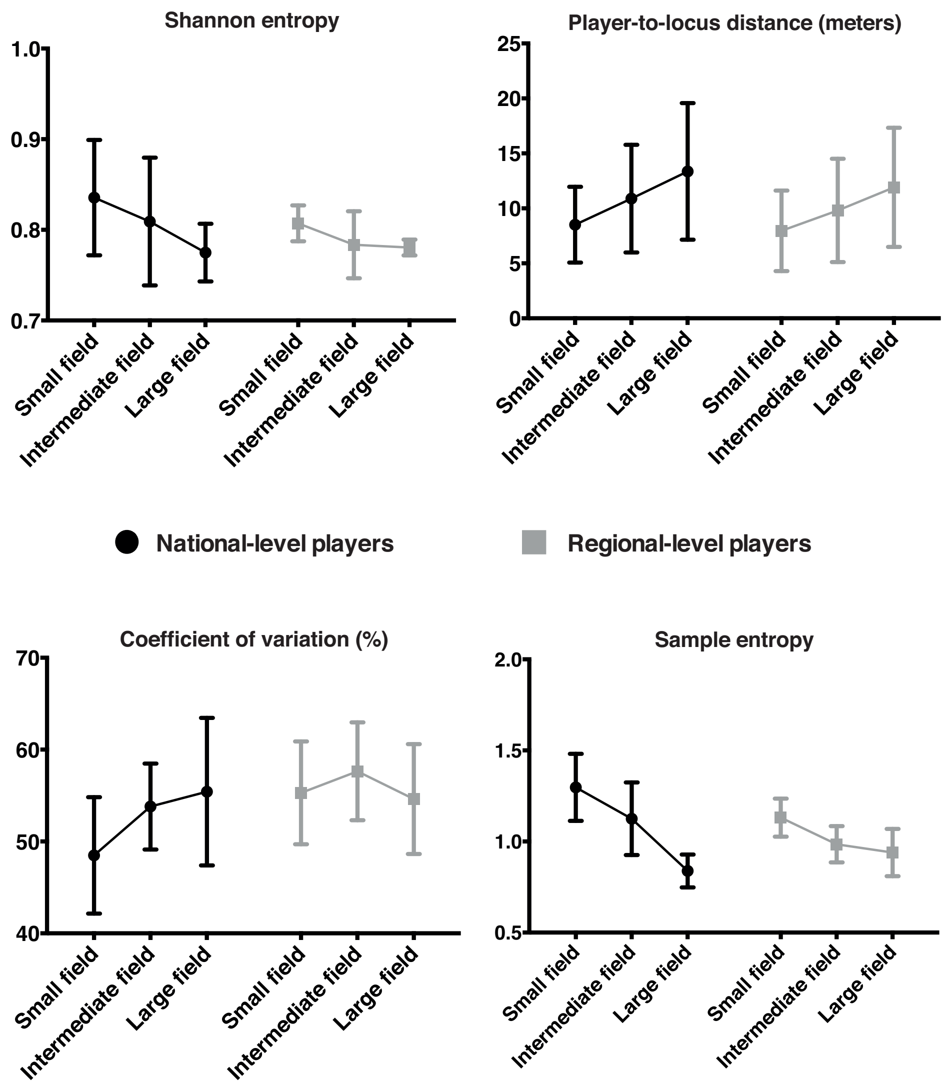

Figure 1. Mean values for Shannon entropy, player-to-locus distance, coefficient of variation and sample entropy. Error bars represent standard deviation.

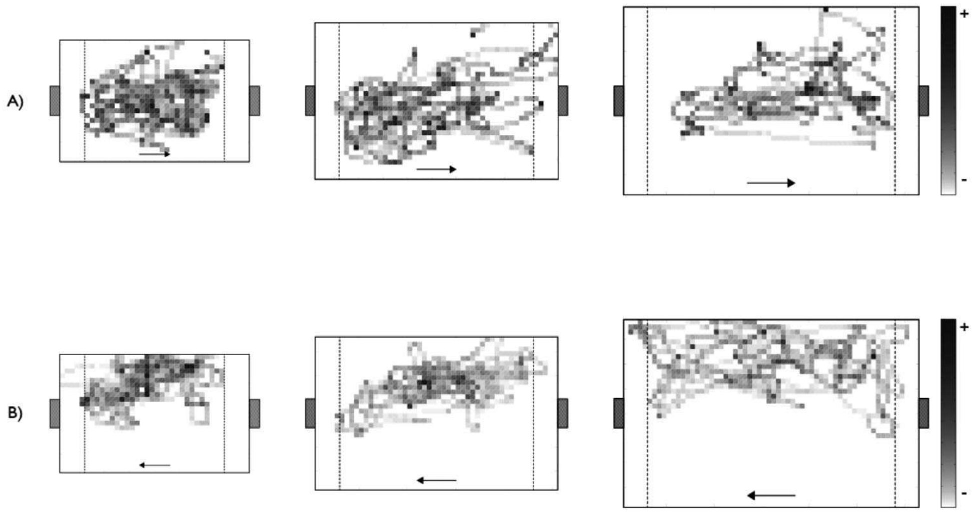

Figure 2. Exemplar spatial distribution maps of two players from each group. A) national-level player; B) regional-level player. Both players usually performed as midfielders in competitive matches. Arrows represent attacking direction. The national-level player presents more variability in bin occupation in relation to the regional-level player in the small and intermediate pitches.

PLAYER-TO-LOCUS DISTANCE VARIABILITY

Exemplar player-to-locus distance (PLdt) time-series of the same players are plotted in Figure 3. Both groups exhibited a sinusoidal signal type, describing near-cyclical movements towards and away from the locus in a relatively periodical fashion.

In both groups, PLdt increased with pitch dimensions (Figure 1, top right panel). A main effect was observed for PLdt by pitch dimensions ($F=79.161$, $p<0.001$, $\eta^2=0.85$), but no interaction effects between pitch dimension and skill level were found ($F=0.82$, $p=0.41$, $\eta^2=0.06$). Post-hoc testing revealed that both groups significantly increased their PLdt across pitches ($p<0.05$ for all comparisons). Significant differences between groups according to pitch were only reported on the intermediate pitch ($p=0.04$).

Coefficient of Variation values increased across pitches for NLP, while RLP presented higher levels in the intermediate pitch and lower levels in the small and large pitches (Figure 1, bottom left panel). No main effects were observed for CV by pitch dimension ($F=2.69$, $p=0.08$, $\eta^2=0.16$). There were no interaction effects between pitch dimension and skill level ($F=2.38$, $p=0.11$, $\eta^2=0.15$).

NLP presented significant differences in CV values between the small and the intermediate pitch ($p=0.02$) and between the small and large pitch ($p=0.01$). The RLP did not show significant differences between any of the pitch dimensions for CV. Groups differed significantly only on the small pitch ($p=0.04$) with RLP presenting higher levels of CV.

Concerning the regularity of PLdt, SampEn values decreased across pitches for both groups (Figure 1, bottom right panel). Significant main effects were found for pitch dimension ($F=21.472$, $p<0.001$, $\eta^2=0.605$) and interaction effects were found between pitch dimension and skill level ($F=5.795$, $p=0.008$, $\eta^2=0.293$). Post-hoc tests for SampEn did not reveal significant differences between groups in any of the pitches. However, p-values close

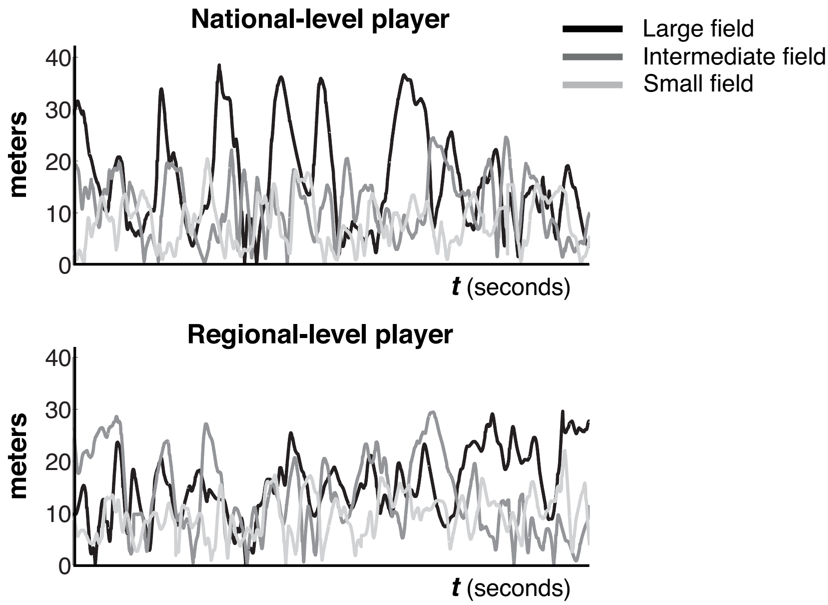

Figure 3. Exemplar player-to-locus distance time-series of the same midfield players presented in Fig. 2. Both exhibit a near-sinusoidal cyclical pattern in all pitches.

to a borderline level of significance were found in the small (p=0.076), intermediate (p=0.087) and large pitches (p=0.064), with higher SampEn mean values being displayed in the small and intermediate pitches for the NLP, and in the large pitch for the RLP. The NLP have significantly decreased their SampEn values across pitches (p<0.05 for all comparisons) but the RLP have only reported significant differences between the small and the intermediate pitch (p=0.050, a borderline value) and between the small and the large pitch (p=0.004). This same group (RLP) did not present a significant decrease in SampEn between the intermediate and the large pitch (p=0.836).

DISCUSSION

This study examined the individual movement variability of young football players during SSCGs as a function of skill level and pitch dimension.

To assess the players' behaviours, linear and non-linear tools were used to analyse the variability of the players' action zones and of their movements toward and away from a personal locus of reference around which actions were developed throughout the performance. These measures provided information about the spatial distribution and movement displacement characteristics such as magnitude of variation and regularity.

SPATIAL DISTRIBUTION VARIABILITY

As pitch size increased, we found more restricted action zones for players of both groups (NLP and RLP). On small and intermediate pitches, players presented more variable action zones, which revealed more uncertainty in their behavioural modes. These data suggested that play was more structured on the large pitch, with players self-organising into specific roles and positions to ensure a balanced occupation of the playing field. Smaller pitches required the players to explore more variable areas of the pitch. This is probably due to greater proximity to opposing players, which limits the available space and time to play [24]. In this context, attacking players needed to move more and explore variable zones in the pitch in order to create free space, while defenders tried to decrease time and space for attacking players [29, 35, 36].

The NLP group presented larger differences in their spatial distributions across pitches than the RLP group, as indicated by effect size values. The former seemed to be more sensitive to modifications in the available area of play and adapted their behaviours accordingly through increased performance regularity as pitch size increased. Despite having decreased their performance variability across pitches, the RLP did not present significant differences between any of the pitches, denoting less sensitivity to specific playing areas.

The NLP group also presented significantly higher variability on the small and intermediate pitches than their less skilled counterparts, but not on the large pitch as hypothesized. Analysis of individual RLPs spatial distribution maps showed that, even on smaller pitches, preferred action zones were identified for some players. On the other-hand, the NLP's spatial distribution maps only identified a predominant action zone on the large pitch (central corridor) while presenting high variable action zones in the small and intermediate pitches. These results clearly showed that players of different skills respond differently to the same task constraints. A possible explanation may be that in smaller pitches, more tackles, shots, challenges, loss of ball possessions and physical contact may occur [21, 37]. These game events are deemed perturbations that change the rhythmic flow of attacking and defending [17, 38]. Therefore, the higher spatial variability presented by NLP may reflect their superior ability in coping with perturbations to stabilize a desired tactical playing configuration to adapt to the SSCGs constraints.

The higher spatial variability of NLP in the small and intermediate pitches may have also been influenced by the different movement preferences of the players, resulting from possessing a higher skill level than RLP. More skilful players adapt better to restricted spaces, whereas less skilful players need larger spaces [39]. Skill is considered to have a major influence on a player's repertoire of possible game play decisions [40], including where to move.

PLAYER-TO-LOCUS DISTANCE VARIABILITY

Results showed that increases in pitch dimensions constrained the players to move further away from their locus. The movements toward and away from the locus were exhibited in both groups within a near cyclical sinusoidal pattern, reflecting the players' tendency to travel around a preferred reference zone during the rhythmic ebb-and-flow of attacking and defending. Despite having presented slightly higher values of PLdt (with significant differences between groups reported only for the intermediate pitch), NLP were more consistent in such distances, by presenting lower percentages of CV in the small and intermediate pitches. Interestingly, despite having shown PLdt measures similar to the NLP, as well as less variable spatial distributions on the small pitch, the RLP also presented less consistent distances to their locus when compared with NLP. In contrast, skilled players searched for and moved to more variable areas of the pitch to cope with the constraints imposed by smaller spaces, while maintaining, at the same time, higher consistency in the distances to their positional locus. This finding might reflect higher perceptiveness of effective space management during performance. Further evaluations of these characteristics need to occur in future studies in order to investigate the advantages of presenting such tactical patterns.

With regard to displacement regularity, both groups of players presented less complex and variable behaviours as pitch size increased. The decrease in SampEn values indicated more regularity in players' displacements around their locus as the space of play became larger. As with spatial variability, the NLP presented a heavy tendency to displace more regularly across pitches when compared to RLP. This, again, suggests a higher degree of sensitiveness to modifications in task constraints.

In the small and intermediate pitches, despite having presented higher consistency in their PLdt, NLP were more irregular on their movements toward and away from the locus. As previously mentioned, they also presented significantly more spatial variability in these pitches. Again, we speculate that higher PLdt variability presented by NLP in the small and intermediate pitches represents optimal variability reflecting superior ability to adapt to the specific constraints imposed during SSCGs practices. Higher unpredictability in movement behaviour may favour the tactical playing patterns required to cope with the available space and time to play and the higher number of perturbations in smaller pitches. Curiously, in the large pitch, NLP displayed slightly higher PLdt values and slightly higher displacements regularity when compared to RLP. Previously, we have reported also their lower spatial variability in this pitch condition. This means that despite having distanced themselves further from their zone of reference, they were still more regular in the zones visited and in their rhythmical movements. This may evidence superior tactical awareness of their playing roles and positional play in larger spaces.

Contrary to our expectations, NLP presented higher regularity than RLP in the large pitch. It is not known how the players can benefit from lower variability levels in the large pitch. In previous research comparing participants of different expertise bouncing a ball it was also found that movement variability increased and decreased as a function of skill and the task being performed [41]. In this case, the decrease in variability may be associated with the positional behaviours adopted in the large pitch. In this SSCG, players performed a more structured play by fixing their positions into more restricted action zones. The extent to which this strategy benefits from low individual movement variability shall be investigated in the future.

PRACTICAL APPLICATIONS

In this study, there are implicit some important messages for practitioners. When designing SSCGs, it should be considered that smaller pitches seem to rehearse game situations resulting in higher unpredictable action zones and less attraction towards the players' spatial positional references, whereas larger spaces seem to appeal to a more structured playing style and more attraction towards spatial positional references. Thus, pitch size manipulations can be used to shape the players' tactical behaviours according to stricter or broader tactical roles. The skill level of the practitioners shall also be accounted since different individual capabilities may result in different tactical adaptations to the SSCG requirements.

CONCLUSION

The findings of this study confirm that both pitch dimension and the players' skill have an influence on their movement variability. Their action zones became more restricted as available playing area increased, suggesting a more structured style of play, according to specific positioning and playing roles (e.g., attacker, defender, right wing, left wing). Players also tended to move more regularly (i.e., periodically) around their positional spatial reference (i.e., the locus). As expected, the most skilled players were more sensitive to pitch size manipulations and presented both higher marked differences across pitches, and significant higher variability in the small and intermediate pitches, meaning that the same task constraints can yield different effects according to the players' competitive standard.

While higher variability in individual movement behaviour may be interpreted as the necessary unpredictability to cope with the reduced time and space available to play in smaller pitches, it is not known how players can benefit from lower movement variability in larger spaces. It seems to exist in association with the degree of structured play and lower levels of variability. In this sense, we suggest future studies to investigate if decreases in individual movement variability are associated with behavioural changes at a team level and vice-versa. Another clarification that is needed in the future is about the functionality of the variability that is reduced. Perhaps skilled players reduce mainly non-functional variability [42].

The findings of this study may be limited in extent by the sample size and by the sequence of SSCGs used in the experimental setting. It is proposed that future investigations attempt to evaluate a higher number of participants using different research designs.

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APPENDIX

AR models of various orders (1 to 10) were fit to the data with the argument that if data come from an AR(p) process then $m \geq p$. Thus, m can be estimated by solving the first p Yule-Walker equations with correlations estimated using the sample autocorrelation coefficients. The order of the process is, then, estimated to minimize the Schwarz's Bayesian criterion that represents a trade-off between the fit of the AR model and the number of parameters estimated [43]. Results yielded 90% of the estimates provided with the AR processes to be between 2 and 5 (Figure 4). Based on this finding, we have used m values ranging from 2 to 5.

The r parameter to be picked shall minimize the efficiency metric $Q = \{\max \sigma CP/CP, \sigma CP/\text{-}\log(CP).CP\}$, which represents the maximum relative error of SampEn and of the conditional probability estimate (CP), respectively. This criterion reflects the efficiency of the entropy estimate because it favours estimates with low variance and simultaneously penalizes CP near 0 and near 1. Thus, for each player time series, it was calculated SampEn and CP relative errors for the range values of m={2, 3, 4, 5} and r=0.1 to 0.8 in steps of 0.1. The players' median values of Q for each (m, r) combination ranged from 0.405 to 0.951. For our data we have selected m=3 and r=0.1 because: (i) m =3 is acceptable because of the AR analysis and (ii) r = 0.1 is the value that better fits m = 3 since it minimizes the quantity Q (for m = 3 and r = 0.1, Q = 0.405, which is the lowest value of the efficiency metric).

For more detailed justifications on these procedures see [44, p. R791].

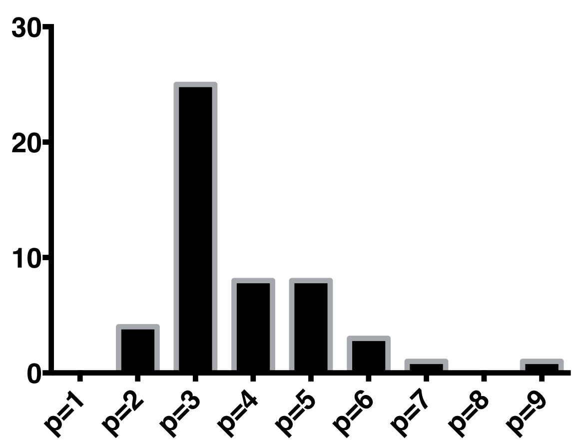

Figure 4. Number of estimates provided with each of the AR model orders.