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SIZE MATTERS: PITCH DIMENSIONS CONSTRAIN INTERACTIVE TEAM BEHAVIOUR IN SOCCER

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Abstract Pitch size varies in official soccer matches and differently sized pitches are adopted for tactical purposes in small-sided training games. Since interactive team behaviour emerges under constraints, the authors evaluate the effect of pitch size (task) manipulations on interactive team behaviour in small-sided soccer games. Four 4-a-side (plus goalkeepers) small-sided games were played: a reference game (30×20 m), length manipulation (24×20 m), width manipulation (30×16 m), and a combination (24×16 m). Using position data (100Hz), three measures quantifying the teams' interaction were calculated: longitudinal inter-team distance, lateral inter-team distance, and surface area difference. Means and standard deviations, correlations and coupling values were calculated. Running correlations were calculated over a 3-s window to evaluate interaction patterns. As expected, a shorter pitch results in smaller longitudinal inter-team distance, lateral inter-team distance decreased for narrow pitches, and smaller total playing area resulted in decreased surface area. Unanticipated, a crossover effect was present; length and width manipulations also triggered changes in lateral and longitudinal direction respectively. Inter-team distances and surface area difference differed significantly across conditions. Interaction patterns differed across conditions for all measures. So, highly tactically relevant, soccer teams seem to adapt their interactive behaviour according to pitch size in small-sided games.

Key words Constraints, dynamics, performance analysis, small-sided games, tactics.

1 Introduction

In complex systems, spatial-temporal patterns arise from local interactions of components that comprise the system. Players are considered to be these interactive components in team sports like rugby, basketball, and soccer. Interactions of players within a team and between players of different teams are thought to give rise to the sport specific patterns[1,2]. The former

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are considered intra couplings, whereas the latter are referred to as inter couplings. Such interactions between players are formed and broken continuously. Normally, local information governs the specific coupling between persons[3]. In this respect, some experimental work has been performed in player-player dyads in basketball[4]. Here, an attacker had to pass the defender in order to score. The aim of the defender was to prevent the goal attempt. So, where the attacker seeks to disrupt the balance in the dyad, the defender aims to maintain balance and remain in position between attacker and basket. One conclusion was that information that specifies the interaction seemed to emerge within the specific performance context.

The same line of reasoning can be applied to team sports game situations that involve more players. Here, the opposition relation between players of different teams means that at every instant, some or all players aim to achieve a specific goal. Whilst doing so, players within a team are cooperating to score a goal, or to prevent the opposition from scoring. Thus, all players cooperate and compete simultaneously. Hereto, continuous player movements are required to choose tactically relevant positions on the field, relative to opponents, teammates, ball, and goals. So, information based on speed and direction of players and ball seem to govern tactical decisions by players[5]. This infers that changes in player positions on the field reflect coupling between players and as such changes in interpersonal distances could therefore be measures of the systems' state[3]. Some evidence confirming this has been provided in basketball[4] and rugby[3]. In similar fashion, a coupling between the two teams is present. Such entrainment of team measures like the teams' centroids (geometrical centers) and surface areas has been established in various studies[6−8]. The surface areas, longitudinal and lateral movements of centroid positions of two teams are thought to reflect the flow of attacking and defending during a match[1,8]. Moreover, both inter-team distances, defined as the distance between two longitudinal or lateral components of teams' centroid positions, seem to be associated with critical and tactically relevant game events following a dynamical analysis of an elite soccer match[9]. So, similar to player-player dyads, the distance between the teams' centroids and difference in surface area reflect the interaction process between teams.

In dynamical systems, the functional interaction patterns expressed in a specific performance context emerge under constraints. In systems like sports, tasks constrain spatial-temporal patterns, next to environment and person-associated factors[10]. Among other tasks[3,11], pitch size is considered to constrain spatial-temporal player behaviour in small-sided soccer games. Pitch size manipulations indicate that, for example, increased relative playing area per player increases exercise intensity and influences players' movement patterns[12]. Besides, it has been suggested that small-sided games are useful technical and tactical training tools frequently used in practice[12−14]. Because pitch size manipulations have shown to affect players' spatial-temporal movement patterns, and players comprise the two interacting teams, we argue that team behaviour, measured by centroid position, and surface area, may also be constrained by pitch size. As a consequence, also the interaction processes between two teams, reflected by inter-team distances or the surface area difference, could be affected by pitch size. However, changes in teams' tactical behaviour and the effects of pitch size manipulations on it, have not been addressed in scientific studies to date. Therefore, the aim of the current study is to evaluate the effect of three pitch size manipulations on longitudinal and lateral inter-team distances and the surface area difference. We expect that decreased pitch length will result in decreased longitudinal inter-team distance, given the same pitch width. Similarly, we expect that decreased pitch width results in decreased lateral inter-team distance, given the same pitch length. Finally, we hypothesize a smaller relative surface area with smaller total playing area.

2 Methods

Ten amateur soccer players (age: 22±3 y; length: 186±6 cm; weight: 78±8 kg) participated in this study. Each player gave informed consent before data collection and all procedures were in accordance with the ethical standards of the Medical Faculty of the University Medical Center Groningen, University of Groningen, The Netherlands.

Four 4-a-side small-sided soccer games plus goalkeepers defending regular FIFA-approved goals (7, 32×2, 44 m) of 8 minutes were played. Eight-minute rest intervals interspersed the games and a 2-hour break separated the morning and afternoon session (2 games each). Prior to each session, a standardized warm-up of 20 minutes was conducted. Pitch dimensions in the first experimental condition (length × width) were 30×20 m. These dimensions correspond with a regular full-sized soccer pitch and are common for 4-a-side games[7,8,12]. In Condition 2, pitch length was reduced which resulted in a 24×20 m pitch. In Condition 3, pitch dimensions were 30×16 m after width manipulation. In the fourth condition (24×16 m), both length and width were shortened, maintaining the same length to width ratio compared to Condition 1. Goalkeepers were restricted to 2-touch play and outfield players were instructed to avoid long-range shots to optimize the flow of attacking and defending. The offside rule was not applied.

The local position measurement (LPM) system (Inmotio Object Tracking BV, Amsterdam, the Netherlands) was used to collect player positions. This technology has been established as an accurate and valid tool to record player positions and speed[15]. All players wore a vest containing a transponder located on the back that was connected to two antennas, one on top of each shoulder. The antennas received radio-frequency signals transmitted by the main base station. After tagging the signal, it was transmitted back to ten base stations surrounding the pitch. From there, data was transported to a server and computer in a command room through glass-fiber technology. Player positions were calculated based on timing differences. Further details are described elsewhere[8,16]. Sampling frequency for an individual player was 100 Hz.

Position data was used to calculate centroid positions and surface areas of both teams[8]. From the centroids of both teams, the inter-team distance in longitudinal (ITDX), and lateral (ITDY) direction were derived, i.e., the absolute distance (m) between the x and y component of the centroid positions, respectively. From the surface areas of both teams, the surface area difference (SAD) was calculated, i.e., the absolute difference (m2) between the surface areas of both teams.

Means and standard deviations of ITDX, ITDY, and SAD were calculated for all games. In addition, Pearson correlation coefficients (r) were calculated between teams' centroid positions and teams' surface areas. Subsequently, R^2-values were determined as this indicates coupling strength between the two teams. Furthermore, running correlations were calculated for centroid and surface area time series over a moving 3-s window. This window was established after consulting a panel of 5 expert coaches on the maximal time allowed for a soccer team to respond to important game events. Evaluation of running correlations is a powerful approach to capture changes in coordination patterns between system components over time[17], here the two teams. Correlations near 1 indicate that the direction of the change is similar for both teams and are associated with in-phase patterns, whereas correlations near -1 mean the direction of the change is opposite for both teams and point toward antiphase patterns. Correlation values of zero specify the absence of a specific pattern within the 3-s window. By rounding each correlation value, we simplified the graphical representation for qualitative evaluation of the running correlations. Values above $0,5$ were rounded to 1, correlations ranging from $-0,49$ to $0,49$ were rounded to 0 and correlations under $-0,5$ were rounded to -1. Finally, for the evaluation of the effect of the experimental manipulations on the ITD and SAD measures, a MANOVA was conducted. SPSS (version 18.0.3, SPSS inc., Chicago, USA) was used for the statistical procedures and statistical significance was accepted if $p < 0.05$.

3 Results

In comparison with Condition 1 (30×20 m), main observations for decreased pitch length (24×20 m) in longitudinal direction are a 15 % decrease ITDX (1.98m vs. 1.66m, respectively) and a reduction in coupling strength (0.81 vs. 0.77, respectively). This is primarily accompanied with an increased proportion of centroids moving in the same direction simultaneously (Figure 1(A)). Furthermore, a decrease in ITDY (1.13m vs. 1.02m) and a reduced coupling strength are observed in Condition 2 (Table 1). Running correlations indicate a decrease in the proportion of simultaneous movement of teams' centroids in the same lateral direction.

Two pairs can be compared for decreased pitch width given the same pitch length: 30×20 m vs. 30×16 m and 24×20 m vs. 24×16 m, respectively. Similar trends are visible for both pairs. In both pairs, a smaller pitch width results in a decreased ITDY and reduced coupling strength between centroid positions. Proportionally, centroid positions move less in the same direction (Figure 1(B)). An additional observation in both pairs is a decrease in ITDX for smaller pitch dimensions. In contrast to lateral displacement of the centroids, an increase in simultaneous displacement in the same direction is found.

A reduction in both pitch length and pitch width with similar length to width ratio (24×16 m) results in the largest decrease in ITDX (1.98m vs. 1.48m, respectively) whilst coupling strength remains the same (0.81). ITDY and lateral coupling strength between centroid positions both decrease on a smaller pitch. Running correlations indicate that centroids proportionally move more in the same longitudinal direction simultaneously (Figure 1(A)) and less in the same lateral direction (Figure 1(B)).

Results for surface area indicate that coupling strength is near zero for all conditions (Table 1). SAD decreases with decreased pitch length (30×20 m vs. 24×20 m) and with smaller witdh (30×20 m vs. 30×16 m). The largest SAD was observed for the smallest pitch dimension (24×16 m). Although running correlations of teams surface areas indicate that proportionally 'no pattern' occurs most frequently (37%–46 %), an attraction towards one of the other patterns is absent, as frequency distributions are similar across patterns (Figure 1(C)).

Table 1 Descriptives of centroid position and surface area. Means ± standard deviations of longitudinal (ITDX) and lateral (ITDY) inter-team distances and surface area difference (SAD) are presented, next to correlations (r) and coupling strength (R^2)

	Centroid position					
	Longitudinal			Lateral		
Game	ITDX (m)	$r_{\text{team1-team2}}$	$R^2_{\text{team1-team2}}$	ITDY (m)	$r_{\text{team1-team2}}$	$R^2_{\text{team1-team2}}$
Condition 1 (30×20 m)	1.98±1.23	0.90	0.81	1.13±0.84	0.86	0.74
Condition 2 (24×20 m)	1.66±1.10	0.88	0.77	1.02±0.77	0.82	0.67
Condition 3 (30×16 m)	1.58±1.10	0.91	0.83	0.96±0.77	0.69	0.48
Condition 4 (24×16 m)	1.48±1.05	0.90	0.81	0.99±0.77	0.73	0.53

	Surface area		
	SAD		
Game	SAD (m^2)	$r_{\text{team1-team2}}$	$R^2_{\text{team1-team2}}$
Condition 1 (30×20 m)	34±29	−0.14	0.02
Condition 2 (24×20 m)	28±21	−0.05	0.00
Condition 3 (30×16 m)	31±25	−0.03	0.00
Condition 4 (24×16 m)	38±31	−0.17	0.03

Note: significant differences between all games for ITDX, ITDY, and SAD.
All correlations are significant at 0.001 level.

4 Discussion

Manipulations of pitch dimensions in small-sided games have shown to influence technical, running patterns and physical responses of soccer players[12]. Therefore, we expected that also spatial-temporal interaction patterns at team level could also be similarly constrained by pitch manipulations, since patterns emerge within a constrained performance context. Thus, the aim of the current study was to evaluate the effect of pitch size manipulations on longitudinal and lateral inter-team distances, and the surface area difference.

In line with our first hypothesis, results indicate a 15% decrease in longitudinal inter-team distance when the pitch is shortened by 20% (30 vs. 24 m). Thus, it appears that reduced pitch length causes players to close in on each other longitudinally. One unanticipated finding is a crossover effect of pitch length reduction on lateral inter-team distance. The decrease in lateral inter-team distance is most likely a side effect of players decreasing the longitudinal distance between each other. So, we argue that as a result of the shorter pitch, players start to play closer together longitudinally. However, adapting position only in longitudinal direction, this would possibly lead to a less optimal position relative to teammates and opponents. Therefore, players also tighten up in lateral direction. Another consequence of the shorter pitch appears to be that the teams' centroids tend to move more in the same direction longitudinally (Figure 1(A)), whereas in the teams' centroids display a decrease of moving in the same lateral direction simultaneously. Finally, the reduced variability of inter-team distance in the shortened pitch condition (1.23 vs. 1.10 m, respectively) supports the argument that teams' interactive behaviour differs across games. Although the degree of variability is high when expressed as a percentage, possibly caused due to skill level, the decrease in variability seems to be proportionate to the decrease in pitch length. This could infer that each team seems to explore action possibilities to the same degree. Yet, future research to this specific issue is warranted. So, the pitch length manipulation clearly affects the inter-team dynamics measured by the distance between teams' centroids.

In similar fashion, our second hypothesis was also confirmed as smaller lateral inter-team distances were observed for conditions with reduced pitch width. Similar to the effect of pitch length manipulation, a reduced width causes players to decrease the lateral distance between each other. Despite this, coupling values are consistently lower in the reduced width conditions. It has been argued that exploiting the available space at the lateral ends by passing the ball towards these regions of the pitch is a means to advance up the field in longitudinal direction as a team[8]. The availability of more lateral space at wider pitches offers players the opportunity to move in to these regions, increasing teams' lateral displacement subsequently. This in turn facilitates entrainment of centroid positions in lateral direction, resulting in higher coupling values. Evaluation of coupling on a 3-s timescale through running correlations indicates that the type of lateral coupling shifts, judged by the decreased proportion of running correlations valued 1 (Figure 1(B)). So teams start to move less in the same lateral direction simultaneously.

An important additional finding is that again, a crossover effect was triggered by the pitch manipulations. Namely, results demonstrate shorter longitudinal inter-team distances for narrow pitches compared to wider pitches. Our rationale is that if players would only reduce their lateral orientation after the manipulation, their positioning in relation to teammates, and opponents is disturbed. Due to this, players choose a different optimal position, hence adapting their longitudinal position also. Even more so, the teams' centroid positions tend to move more in the same direction during the game. Taking this together, interactive team behaviour, represented by teams' centroids, is altered in lateral and longitudinal direction following pitch width reductions.

In the final manipulation, length and width were reduced both to create a pitch with the

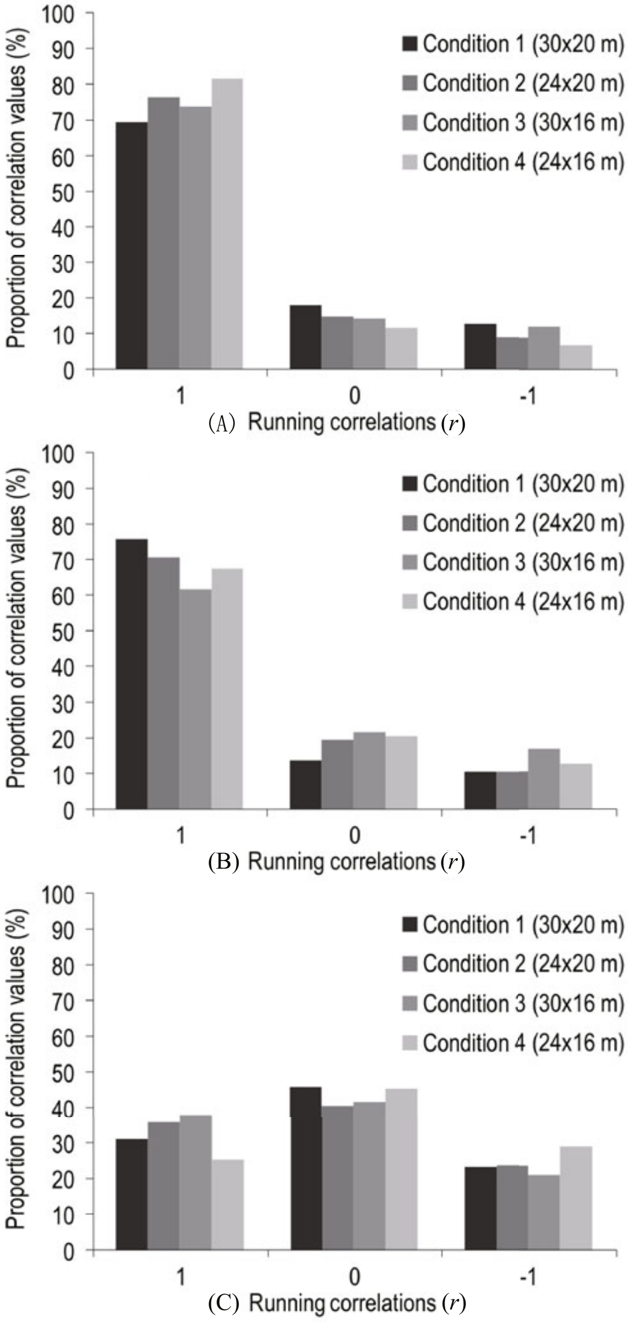

Figure 1 Histograms displaying proportion of running correlations of (A) longitudinal centroid positions, (B) lateral centroid positions, and (C) surface areas of the teams. Correlations of 1 indicate changes in the same direction, correlations of −1 indicate changes in opposite direction and correlation of 0 indicate no specific pattern

same length to width ratio compared to Condition 1. Main observation was that all effects of the manipulations on inter-team distances as observed in the length only or width only conditions were present. Moreover, the decrease in longitudinal inter-team distance was proportionate to the decrease in pitch length (25% and 20%, respectively), without a change in coupling strength. Paradoxically, the largest average surface area difference and stronger attraction to antiphase were established in this condition. As stated before, the shorter longitudinal and lateral inter-team distances indicate shorter distances between players. Most likely, it becomes easier for players of the defending team to recover the ball by collectively restricting space. In its turn, the small pitch ensures that not too much space becomes available laterally for the attacking team to exploit. Consequently, if players performed a similar act of restricting space on a larger pitch, they probably give away too much space laterally. So, players seem to use the natural boundaries of the pitch differently on a smaller pitch, resulting in a stronger pattern and a larger surface area difference. Thus, a smaller field with identical length to width ratio seems to result in different interactive team behaviour compared to a larger pitch.

In regard to the other findings for teams' surface areas, we established limited differences across conditions as coupling values are low, congruent with earlier findings[7,8]. An attraction to a specific pattern was absent (Figure 1(C)), partially agreeing with previous findings as others found a bistable attraction for relative stretch indexes, a comparable measure of team dispersion[6]. In our study, proportion of 'no pattern' was highest in all games. The proportions of simultaneous changes of surface are in similar direction and opposite direction were comparable but lower compared to 'no pattern'. A large reduction in pitch size results in a small decrease in relative surface area. To us, this indicated that teams' occupy similarly sized playing areas with decreased pitch size. So, although emergent patterns differ minimally across game conditions, the absolute surface area differs across conditions as expected.

Finally, although caution must be taken given the small sample size, our results correspond with previous research overall[6,8,18]. To illustrate, we demonstrated that the strongest coupling strength between teams was found for coupling for longitudinal parameters and weaker coupling was observed for lateral parameters. Yet, correlation values in this study for specifically longitudinal and lateral centroid positions are lower than those observed in previously[7,8]. Perhaps, expertise level underlies this observation. In this study, amateur soccer players participated, whereas elite youth players participated in other studies. It has been shown that expert soccer players can extract more pertinent information related to player movements through peripheral vision[18] and anticipate more quickly to their environment[19]. As less gifted soccer players are less able to anticipate movements of teammates and opponents, team measures based on individual player positions like centroid positions are less coupled presumably. This may imply that absolute values of inter-team distances are key performance indicators, whereas the strength of the relation is an indicator of playing level. However, as this study provides no evidence for the degree in which the teams' expertise level influenced the results, future research in this area is warranted.

5 Conclusions

We examined the effect of pitch size manipulations on surface area difference, longitudinal and lateral inter-team distances, and spatial-temporal patterns thereof. As expected, manipulations of pitch length and width sparked changes in team measures in those directions respectively. Most importantly, we also showed that there is a crossover effect of pitch length manipulation on lateral inter-team distance and from pitch width manipulations on longitudinal inter-team distance. In sum, we showed that changes in pitch size trigger changes in teams' interactive behaviour in small-sided soccer games. This is an important tactically relevant finding that, when aware of, coaches can use to their advantage in training and matches.

6 Practical implications

1) Pitch size manipulations of length and width affect teams' spatial-temporal interaction patterns in that particular direction.

2) The crossover effect of length and width manipulations indicate that changes in either one triggers a response by teams in both directions.

3) Coaches must carefully choose the type of small-sided game in training, as interaction patterns vary depending on pitch dimensions.

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