Sports Science

The macro- and micro-adaptations in the football teams

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Abstract - Aim: This study investigated the adaptations of football teams as hierarchically organised open systems. In this type of system, the collective and individual behaviours are characterised by consistency and variability, respectively. **Methods:** Five professional men's football matches in the under-20 category were analysed. The team's centroid as a measure of the system's macrostructure and the distance from each player to the team's centroid (a measure of the system's microstructure) were obtained from the players' *x* and *y* coordinates of displacement on the soccer field. Cluster analyses were run using Ward's minimum variance method with Euclidean distance. **Results:** (i) teams showed consistency and variability in their macro- and microstructures, respectively; (ii) there was a correlation between attack and defence patterns in most game sequences; (iii) goals were scored when teams modified their macro and/or microstructure. **Conclusion:** Football teams showed correspondence in attack-defense patterns with macro-consistency and micro-variability throughout the match. Despite this, there was no relationship between the foregoing patterns and game outcomes. Goals were scored after changes in the team's structure.

Keywords: hierarchy, interaction, collective behaviour, game analysis.

Introduction

Football (soccer) is one of the most important sociocultural phenomena in the contemporary world. It is a human motor activity whose essence is systemic, that is, lies in the interactions among the players. The game of football develops based on two types of interaction: cooperation (intra-team interaction) and opposition (inter-team interaction)[1-3].

From a systemic point of view, football players cooperate to perturb the opposing team to score a goal (attack) or to recover the ball (defence)[1,4,5]. A perturbation concerns any event that causes a change in the system[6]. The fact that both teams seek to perturb each other simultaneously and continuously makes the game an adaptive process since the teams must continually adapt to the opponent's perturbation[4]. Adaptation refers to the alteration of a system to deal with the internal or external conditions that are changing[7,8].

Recently, numerous studies have been developed to understand the adaptations in the game of football by considering the team or the components (for example, 11 versus 11 or 1 versus 1 situation, respectively) changes[9-13]. Notwithstanding the advances provided by these studies, the evidence has described either collective or individual behaviour, but not both levels as complementary. In addition, studies have not considered the association between the team and individual actions with and without ball possession. Therefore, how one team perturbs the other in attack and defence situations throughout the game remains unexplored.

In this regard, in the last few years, the concept of hierarchically organised open systems[14,15] has been used to understand and explain the performance in sport contexts by considering collective and individual behaviours as complementary phenomena (for example, see Corrêa et al.[16]). A hierarchically organised open system is a multilevel organization in which the superior hierarchical level does not absolutely control the inferior level, it only constrains the interaction among its parts[17]. For instance, cooperation in football teams is constrained by the rules of the game, which results in the emergence of collective configuration (superior level). However, within the collective configuration, players (inferior level) make decisions to variate their behaviours according to the game context. In terms of motor behaviour, these levels have been named as macrostructure and microstructure, respectively[6,8,18].

The main advantage of adopting a hierarchically organised open system conception for studying the sport of football refers to the possibility of identifying the different ways in which adaptation takes place[4,16]. In the last few years, studies have been developed under this hierarchically organised open system conception to understand adaptation in different sports, such as swimming[19], golf[20], and futsal[4]. Regarding the latter, evidence showed that the game develops as an adaptive process through micro and macro reorganisation by both teams. Despite this, clear measures have not been provided as to what the changes in microstructure were referring to, also, it was not described the relationship between patterns and game outcomes was. In addition, although futsal is a type of football, it involves a significantly smaller number of players and a smaller playing field.

Accordingly, assessing the different levels in which sport teams modify to cope with the opponent remains unexplored. Thus, this study sought to investigate the adaptations of football teams understood as hierarchically organised open systems. Specifically, it aimed to: (i) identify the teams' macro-microstructure patterns throughout attacks and defences; (ii) verify the relation between the attacks and defences' macro-microstructures as they work in relation to each other, and (iii) analyse the macro-microstructure patterns in relation to attack outcomes.

Method

Sample

The sample consisted of all 738 attack and defence sequences of five under-20 matches during the Paulista Championship and the Brazilian Cup. Three teams (A, B, and C) formed by 71 professional male football players participated in those matches. The attack and defence sequences were n = 142 (match 1); n = 173 (match 2); n = 139 (match 3); n = 148 (match 4); and n = 136 (match 5). The research protocol (87473417.4.0000.5391) was approved by the local Institutional Review Board.

Data collection

The matches were recorded using two digital video cameras, GoPro HERO 3+ Black Edition (GoPro, San Mateo, CA, United States), set to a resolution of 1920 x 1080 pixels, a narrow angle of the caption, and a frequency of 30 frames per second. Each camera was mounted on a tripod and located in the lateral grandstand of the pitch. The first four matches took place on pitches measuring 105 m x 68 m and, the fifth match took place on a pitch measuring 116 m x 75 m.

Data analysis

Data were digitised using the *Dvideo* software[21], widely used in football analysis[13,22]. The software *RStudio*, Version 1.1.456 (RStudio: Integrated Development Environment for R. Boston, MA, United States) was also used to organise and calculate data. First, videos were converted to a resolution of 960 x 640 pixels. Then, for each half of the field, seven points were calibrated, and then, the calibration of both videos was synchronised using points 2, 7, and 8 (Figure 1). After that, all players were identified and tracked, obtaining a matrix with the x and y coordinates of each player. When a player was substituted, the tracking was continued with the substitute player. To assess the reliability of the tracking, one player was tracked two times and a Pearson correlation test was run for x and y separately through the *cor.test* function of the *stats* package in *RStudio* software. Results revealed $r = 0.997$, $p < 0.05$ and $r = 0.998$, $p < 0.05$, respectively. Each track passed through a low pass Butterworth filter of third order at a frequency of 0.4 Hz[23] using the functions *butter* e *filtfilt* of the *signal* package.

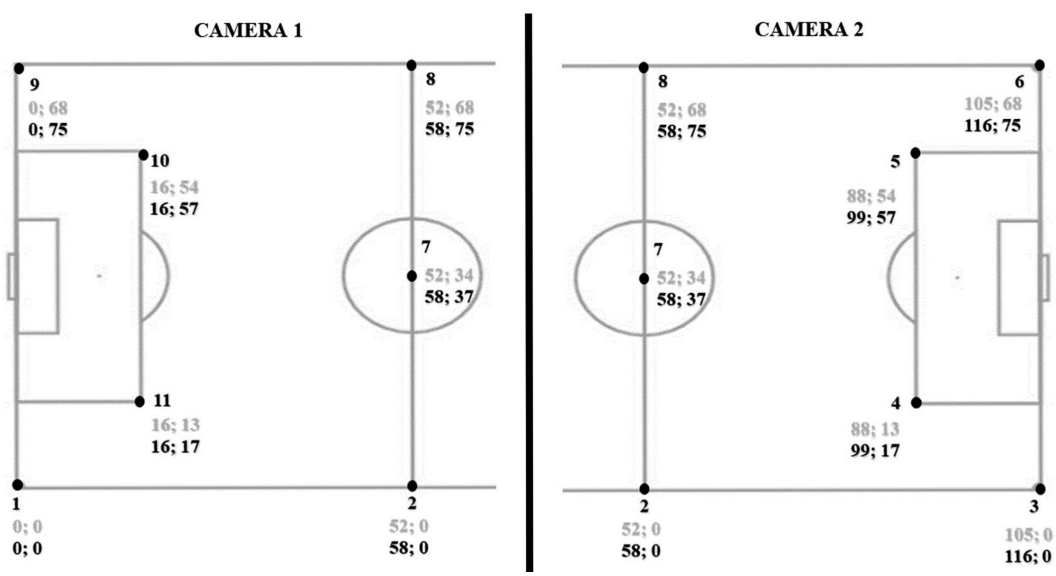

Figure 1 - Calibration points (1 to 11) for each half of the pitch and the respective position for a field measuring 105 m x 68 m (grey) and 116 m x 75 m (black).

The sequences of the game were defined based on the ball possession, that is, from the moment a team gained control of the ball, until the moment it was lost after a shot, a mistake, or a recovery by the defending team. From the database with the position of each player throughout the game, scripts were written to separate the attacks performed by each team and to organise them sequentially, as well as to calculate the spatiotemporal variables of macro and microstructures, as follows:

Macrostructure. Assessed through centroid (C) (Figure 2), considered as the geometrical centre of the team, by using:

$$XT(t) = \frac{1}{n}\sum_{i=I}^{n} XAi(t), \quad YT(t) = \frac{1}{n}\sum_{i=I}^{n} YAi(t)$$

where X and Y are the axes, T is the team, t is the time in frames and n is the number of players. The mean value of the centroid's position was selected in each attack sequence and each defence sequence.

Microstructure. Assessed through the distances (dp) between each player and the centroid (Figure 2), which was calculated using:

$$dp = \sqrt[2]{\left(P_X - C_X\right)^2 + (P_Y - C_Y)^2}$$

where P is the player and C is the centroid. The mean value of the distance of each player to the centroid was selected from each attack sequence and each defence sequence.

Since attacks and their respective defences occurred sequentially, it was possible to infer the patterns of macro and microstructures throughout each game. In addition, it was possible to identify the behaviours (macro and micro-patterns) the teams used to deal with each other. At the end, macro- and microstructures were analysed in relation to a match outcome: (1) attacks completed with a successful shot (scored goal); (2) attacks completed with an unsuccessful shot; (3) attacks concluded with the loss of the ball in the midfield of the defending team; (4) attacks concluded with the loss of the ball in the midfield of the attacking team.

Statistical analysis

Cluster analyses were run using Ward's minimum variance method with Euclidean distance[24] for macrostructures (MA) and microstructures (MI) of each team by considering all attack and defence sequences in each match. The product of this cluster analysis is a tree diagram referred to as a dendrogram that shows the similarity level in the *y-axis*, and each attack or defence is represented in the *x-axis*. *Agnes* and *pltree* functions of the *cluster* package in *RStudio* software were used for cluster analysis and plotting. Based on observations of distinctness, compactness, and weight of the clusters, a cut-off level of 25% of the total height of the dendrograms was assigned[25]. For instance, Figure 3 shows the dendrogram representing six patterns of macrostructure (Ma^1, Ma^2, Ma^3, Ma^4, $MaMa^5$, and Ma^6) of team A throughout 71 sequences of attack in match 1.

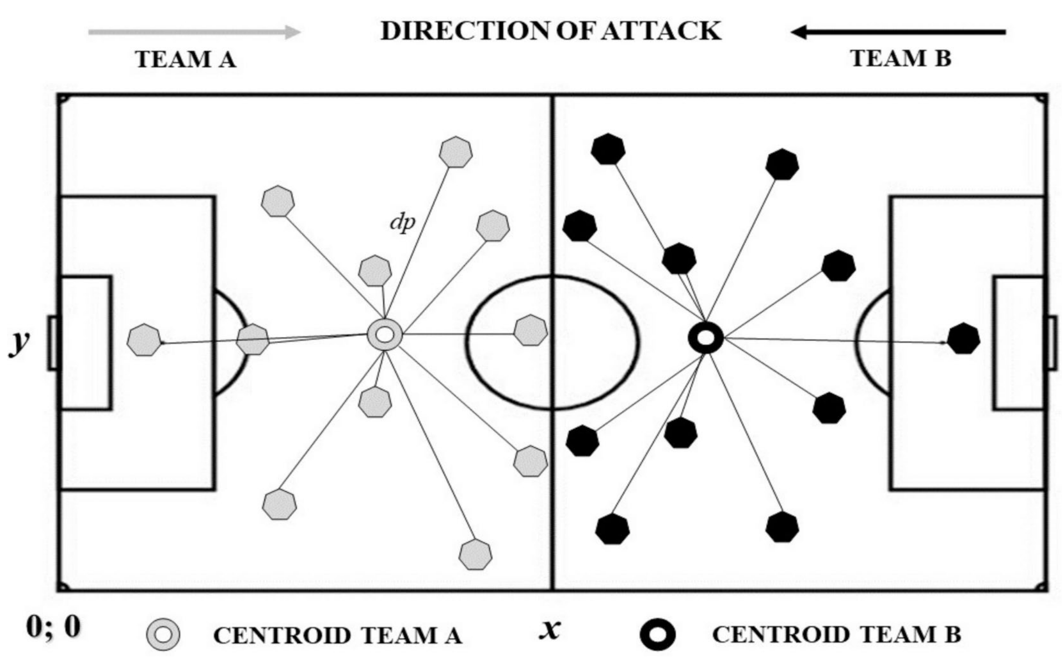

Figure 2 - Illustration of the players, centroid, distances between each player, and the centroid of their team (dp).

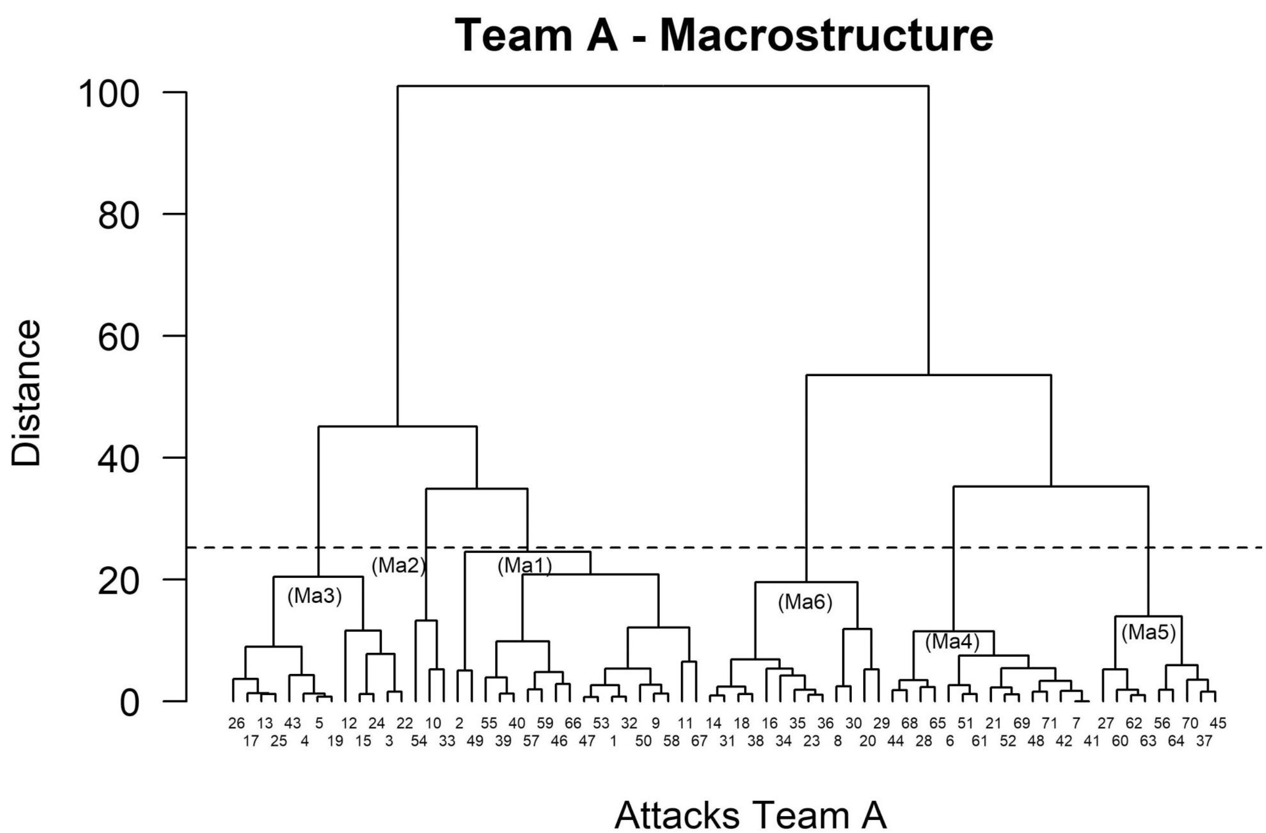

Figure 3 - Dendrogram representing six macrostructure patterns of team A (Ma1, Ma2, Ma3, Ma4, Ma5 e Ma6) throughout 71 attack sequences in match 1.

Results

Identifying macro-microstructure patterns

Table 1 shows the patterns performed in the first three matches. Teams performed different patterns of macrostructures in attacks and defences, which varied from five (for example, match 1, team B, attack) to nine (for example, match 3, team A, attack). Still, macrostructures were composed of different numbers of microstructures, which ranged from one (for example, match 1, team A, Ma3 in attack) to six (for example, match 3, team A, Ma1 in attack). Regarding the number of patterns in attacks and defences, results revealed that teams varied more in attacks than in defences.

Results also indicated that in the five matches, teams adapted by modifying macro and/or microstructure patterns. Taking Figure 4 as an example, the attacking team showed: (1) sequences with the same macro and microstructures, for example [Ma^3-Mi^4 (3-4-5; 12-13; 24-25-26); Ma^4-Mi^5 (6-7; 41-42)]; (2) sequences with the same macrostructures while modifying the microstructure, for example [Ma^1-Mi^1→ Ma^1-Mi^3 (1-2); Ma^1-Mi^5→ Ma^1-Mi^1 (46-47); Ma^1-Mi^3→ Ma^1-Mi^1 (49-50)]; (3) sequences in which the macrostructure was modified, for example [Ma^1 → Ma^3 (2-3; 11-12), Ma^3 → Ma^4 (5-6; 43-44); Ma^4 → Ma^6 (7-8; 28-29); Ma^6→ Ma^1 (8-9; 31-32; 38-39); Ma^1 → Ma^3 (9-10; 32-33; 53-54); Ma^3 → Ma^1 (10-11; 54-55); Ma^3 → Ma^6 (13-14; 15-16; 17-18; 19-20; 22-23)].

Macro-microstructure of attack versus macro-microstructure of defence

Results revealed that in all matches, teams showed pairing between attack and defence patterns in most game sequences. That is, each attack pattern interacted with a correspondent defence pattern throughout the game. For instance, Figure 5 illustrates team A's attacks interacting with team B's defences in match 1. For example, it shows pairing between attacks Ma^1-Mi^1 and defences Ma^2-Mi^3 during attacks 9, 32, 47, 50, 53, 58, and 67; attacks Ma^1-Mi^3 and defences Ma^2-Mi^2 in the sequences of attacks 2, 11, and 49; attacks Ma^3-Mi^4 and defences Ma^1-Mi^1 during attacks 3, 5, 12, 13, 15, 17, 19, 22, 24, 25 and 26; attacks Ma^4-Mi^5 and defences Ma^4-Mi^5 in attacks 6, 7, 21, 41, 42, 44, 48, 51, 52 and 69; attacks Ma^5-Mi^7 and defences Ma^5-Mi^6 along attacks 27, 37, 45, 56, 64 and 70; and, attacks Ma^6-Mi^9 and defences Ma^6-Mi^8 during attacks 14, 16, 18, 23, 31, 34, 35, 36 and 38.

On the other hand, it was verified that a few attack patterns did not have a corresponding defence pattern. In match 1, pairing between the attack and the defence pat-

Table 1 - Teams' macrostructures (Ma) and microstructures (Mi) in attacks and defences in each match.

Match	Attacking Team	Attack	Defending Team	Defence
1	A	Ma^{1} (Mi$^{1, 3, 5, 6}$) Ma^{2} (Mi$^{2, 4}$) Ma^{3} (Mi^{4}) Ma^{4} (Mi$^{5, 6, 8}$) Ma^{5} (Mi$^{7, 8}$) Ma^{6} (Mi^{9})	B	Ma^{1} (Mi$^{1, 3}$) Ma^{2} (Mi^{2,3}) Ma^{3} (Mi^{4}) Ma^{4} (Mi$^{1, 5, 6, 8}$) Ma^{5} (Mi$^{6, 8}$) Ma^{6} (Mi$^{7, 8}$)
	B	Ma^{1} (Mi$^{1, 2, 3}$) Ma^{2} (Mi$^{2, 3}$) Ma^{3} (Mi$^{3, 4}$) Ma^{4} (Mi$^{5, 7}$) Ma^{5} (Mi$^{4, 5, 6, 7}$)	A	Ma^{1} (Mi$^{1, 2, 3}$) Ma^{2} (Mi$^{1, 2}$) Ma^{3} (Mi^{3}) Ma^{4} (Mi$^{3, 4}$) Ma^{5} (Mi$^{5, 6}$) Ma^{6} (Mi^{6})
2	A*	Ma^{1} (Mi^{1,4}) Ma^{2} (Mi$^{1, 2, 5, 7}$) Ma^{3} (Mi$^{2, 3}$) Ma^{4} (Mi$^{3, 4}$) Ma^{5} (Mi$^{5, 7}$) Ma^{6} (Mi$^{5, 6}$)	B	Ma^{1} (Mi$^{1, 7}$) Ma^{2} (Mi$^{2, 6, 10}$) Ma^{3} (Mi^{3}) Ma^{4} (Mi$^{3, 4, 5, 6, 7}$) Ma^{5} (Mi^{5}) Ma^{6} (Mi$^{3, 8, 9}$) Ma^{7} (Mi$^{2, 8, 9, 10}$)
	B	Ma^{1} (Mi$^{1, 2, 4, 9}$) Ma^{2} (Mi^{3}) Ma^{3} (Mi$^{2, 4, 10}$) Ma^{4} (Mi$^{2, 9}$) Ma^{5} (Mi$^{1, 5, 7, 8, 9}$) Ma^{6} (Mi$^{5, 7}$) Ma^{7} (Mi$^{6, 7, 8}$)	A*	Ma^{1} (Mi$^{1, 2}$) Ma^{2} (Mi$^{1, 3, 4, 6}$) Ma^{3} (Mi$^{3, 6}$) Ma^{4} (Mi$^{5, 6, 8}$) Ma^{5} (Mi$^{5, 6, 7, 8}$) Ma^{6} (Mi$^{6, 8}$)
3	A	Ma^{1} (Mi$^{1, 2, 3, 6, 7, 8}$) Ma^{2} (Mi$^{2, 3, 4, 6, 13}$) Ma^{3} (Mi$^{1, 7, 11, 12, 13}$) Ma^{4} (Mi^{11}) Ma^{5} (Mi$^{1, 13}$) Ma^{6} (Mi^{12}) Ma^{7} (Mi$^{5, 8, 10}$) Ma^{8} (Mi^{9}) Ma^{9} (Mi$^{2, 3, 4, 5, 6, 10}$)	B*	Ma^{1} (Mi^{1}) Ma^{2} (Mi^{2}) Ma^{3} (Mi$^{8, 10}$) Ma^{4} (Mi$^{1, 3, 4}$) Ma^{5} (Mi$^{4, 5, 12}$) Ma^{6} (Mi$^{5, 6, 9, 10}$) Ma^{7} (Mi$^{11, 12}$) Ma^{8} (Mi$^{6, 7}$)
	B*	Ma^{1} (Mi$^{1, 6, 9}$) Ma^{2} (Mi$^{8, 9}$) Ma^{3} (Mi^{10}) Ma^{4} (Mi^{2}) Ma^{5} (Mi$^{1, 3}$) Ma^{6} (Mi$^{4, 5}$) Ma^{7} (Mi^{7})	A	Ma^{1} (Mi$^{1, 3, 4, 5, 11}$) Ma^{2} (Mi$^{1, 3, 4, 5, 6}$) Ma^{3} (Mi$^{1, 2, 3, 5, 6}$) Ma^{4} (Mi$^{1, 5, 7, 8, 9}$) Ma^{5} (Mi$^{8, 9, 10, 13, 14}$) Ma^{6} (Mi$^{10, 11, 12}$)

*Team won the match.

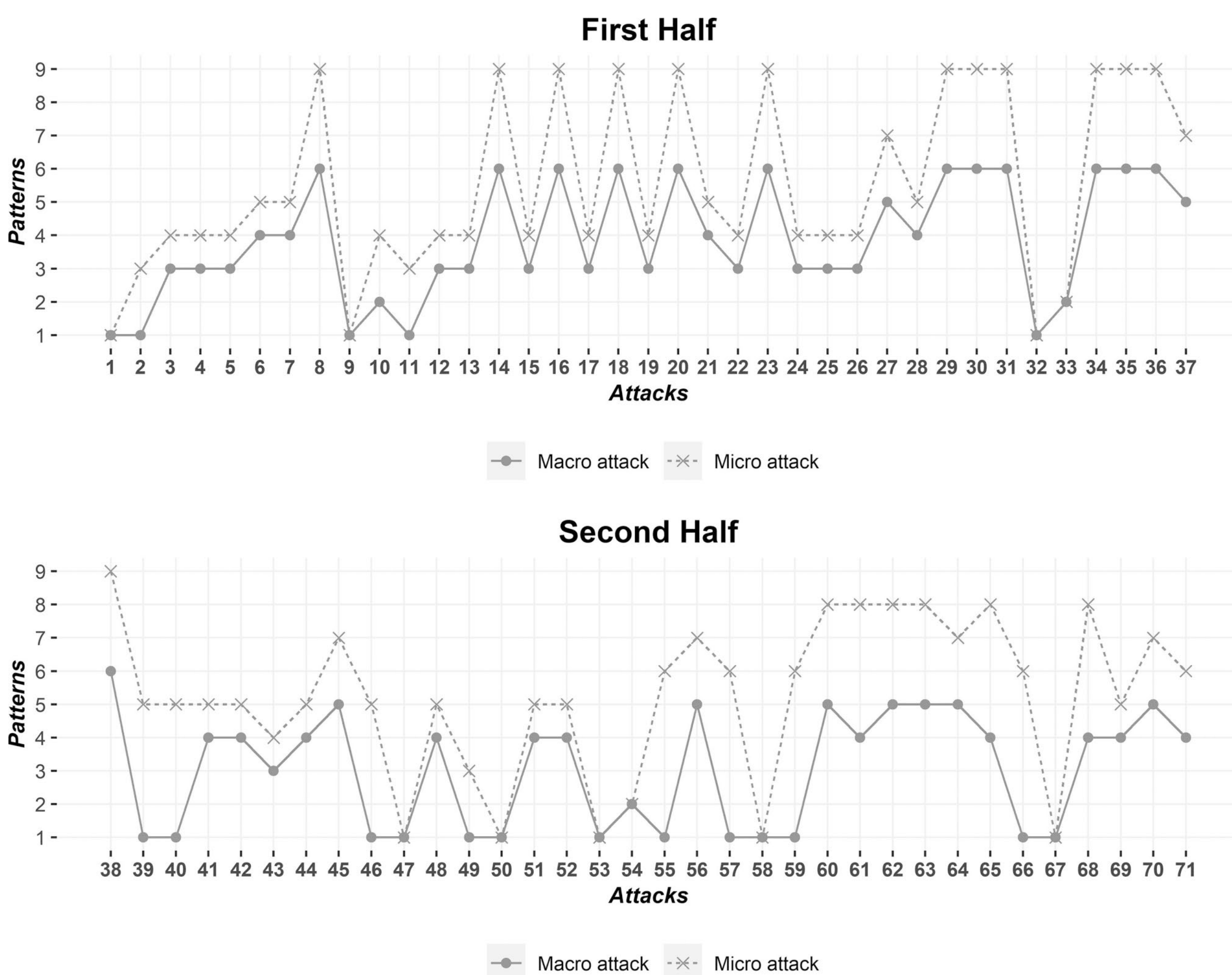

Figure 4 - Macro and microstructure patterns of team A throughout the game.

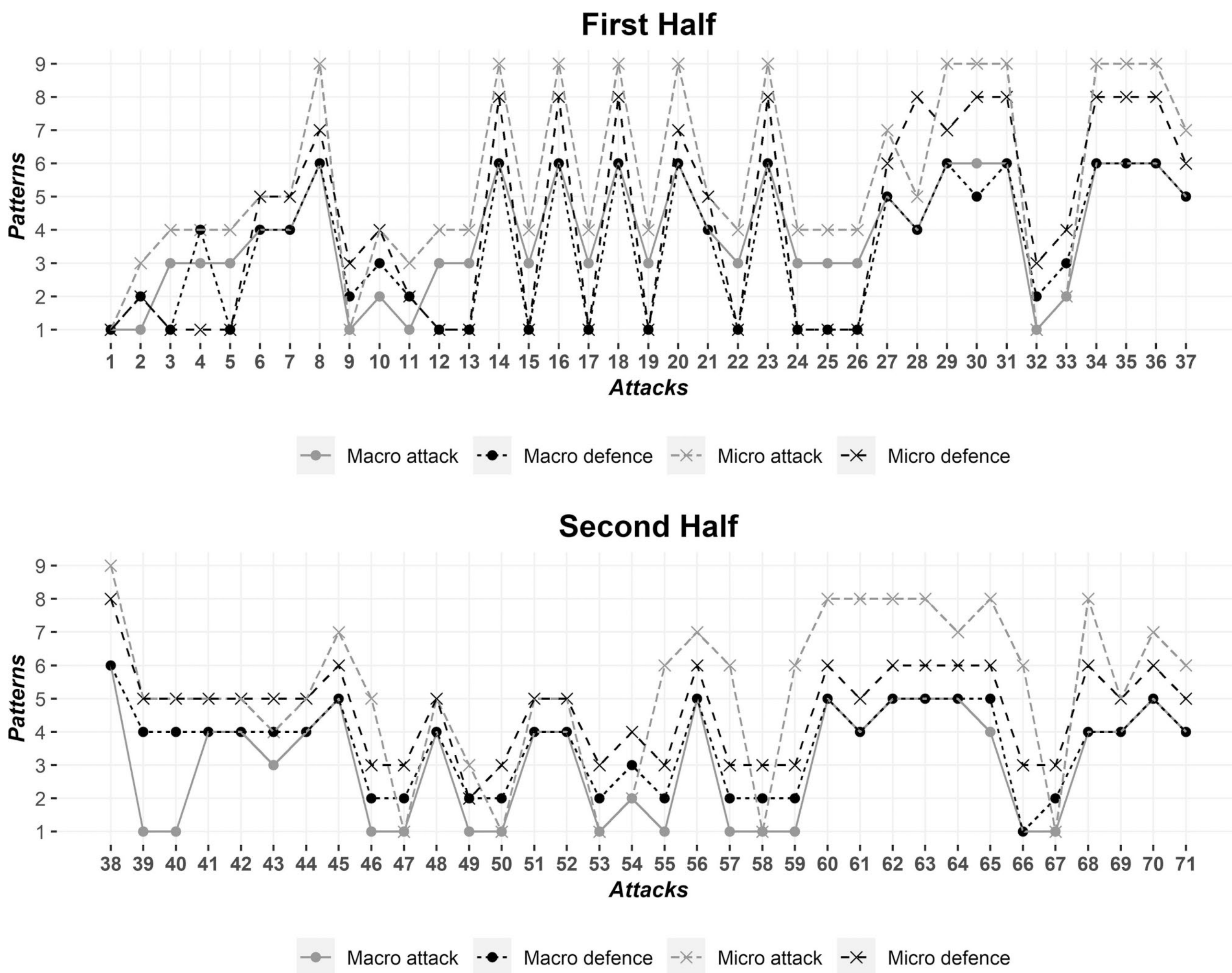

Figure 5 - Macro and microstructure patterns of teams A (grey) and B (black) throughout the game.

terns was identified in 59 (83.09%) out of 71 attack sequences. Of those 59 attacks, 46 attacks (77.96%) finished with outcomes 3 and 4. So, out of 71 attack sequences, in 46 (64.78%) the attack and defence patterns corresponded, and the defending team regained possession of the ball without yielding a shot to goal. In four (33.3%) out of 12 attacks without pairing, the attacking team shot to goal. So, in four (5.63%) out of 71 attacks, the teams' patterns showed no pairing, and the attacking team shot to goal.

Macro-microstructure patterns and attack and defence outcomes

Results showed that the same outcome was reached through the combination of different attack and defence patterns. On the other hand, the same attack/defend combination resulted in two or three different outcomes. These results can be observed, for example, in relation to the macro-microstructure patterns in match 2 (attacks team A versus defences team B) (Table 2).

Specifically, in successful attacks (goal) (Table 3), results revealed changes in either the micro or the macrostructure of the attacking or the defending team in relation to the previous attack. It was found that in most of the goals, the attacking and defending teams modified their macrostructure from the previous attack. Besides that, in five of the nine scored goals (Table 3), attack patterns were exclusively performed in that respective attack. In the same way, in four of those five attacks, the defend patterns were performed in that defence, only.

Discussion

This study aimed to analyse and describe the adaptations of football teams when approached as hierarchical organised open systems. Results revealed that the teams performed a smaller number of macrostructure patterns when compared to those of microstructures. In fact, it was observed that each macrostructure involved different numbers of microstructures, which ranged from one to six.

Table 2 - Macro-microstructure patterns of match 2 (attacks team A versus defences team B) and achieved the outcome. The numbers in parentheses refer to the game sequence.

Attack outcome	Team a's attack vs. team b's defence
Successful attacks (goal scored)	Ma^4-Mi^4 vs. Ma^4-Mi^4 (31)
Attacks completed with an unsuccessful shot	Ma^1-Mi^1 vs. Ma^1-Mi^1 (28, 39); Ma^4-Mi^3 vs. Ma^4-Mi^4 (15, 30); Ma^4-Mi^4 vs. Ma^4-Mi^4 (18, 48); Ma^1-Mi^4 vs. Ma^4-Mi^4 (35); $Ma^4$3e Mi^3 vs. Ma^4-Mi^3 (13); Ma^4-Mi^4 vs. Ma^4-Mi^7 (75)
Attacks concluded with the loss of the ball in the defending team's midfield	Ma^2-Mi^2 vs. Ma^2-Mi^6 (84, 86); Ma^3-Mi^2 vs. Ma^3-Mi^3 (10, 40, 49); Ma^3-Mi^2 vs. Ma^3-Mi^6 (69, 74); Ma^1-Mi^1 vs. Ma^1-Mi^1 (1, 5, 26, 27, 33, 34, 42); Ma^4-Mi^3 vs. Ma^4-Mi^4 (20, 29, 45); Ma^1-Mi^1 vs. Ma^1-Mi^7 (53, 66, 73); Ma^1-Mi^1 vs. Ma^3-Mi^6 (52); Ma^2-Mi^2 vs. Ma^3-Mi^6 (72); Ma^2-Mi^5 vs. Ma^2-Mi^2 (4, 41); Ma^5-Mi^5 vs. Ma^6-Mi^8 (2); Ma^5-Mi^7 vs. Ma^6-Mi^8 (23); Ma^5-Mi^7 vs. Ma^6-Mi^9 (64, 77); Ma^6-Mi^5 vs. Ma^2-Mi^2 (9, 37); Ma^6-Mi^5 vs. Ma^2-Mi^{10} (63, 78); Ma^6-Mi^6 vs. Ma^2-Mi^2 (17); Ma^6-Mi^6 vs. Ma^2-Mi^{10} (81); Ma^6-Mi^6 vs. Ma^7-Mi^{10} (83); Ma^1-Mi^4 vs. Ma^4-Mi^7 (70); Ma^2-Mi^1 vs. Ma^1-Mi^7 (55); Ma^2-Mi^5 vs. Ma^1-Mi^7 (60); Ma^3-Mi^2 vs. Ma^6-Mi^9 (58); Ma^3-Mi^2 vs. Ma^3-Mi^3 (10, 40, 49); Ma^3-Mi^2 vs. Ma^3-Mi^3 (10, 40, 49); Ma^3-Mi^3 vs. Ma^3-Mi^3 (24); Ma^3-Mi^3 vs. Ma^3-Mi^3 (57); Ma^3-Mi^3 vs. Ma^4-Mi^6 (82); Ma^4-Mi^4 vs. Ma^4-Mi^4 (36, 51); Ma^4-Mi^4 vs. Ma^1-Mi^1 (44); Ma^4-Mi^4 vs. Ma^5-Mi^5 (65); Ma^4-Mi^4 vs. Ma^4-Mi^5 (67); Ma^5-Mi^5 vs. Ma^6-Mi^8 (2)
Team A's attacks concluded with the loss of the ball in the attacking team's midfield	Ma^2-Mi^1 vs. Ma^1-Mi^1 (8, 38); Ma^2-Mi^1 vs. Ma^2-Mi^2 (47); Ma^5-Mi^7 vs. Ma^7-Mi^8 (43, 68); Ma^5-Mi^7 vs. Ma^7-Mi^9 (54, 62); Ma^6-Mi^6 vs. Ma^7-Mi^8 (6, 25); Ma^1-Mi^1 vs. Ma^1-Mi^7 (61); Ma^2-Mi^2 vs. Ma^3-Mi^6 (80); Ma^2-Mi^5 vs. Ma^2-Mi^2 (7, 16, 22, 46); Ma^5-Mi^5 vs. Ma^6-Mi^8 (21); Ma^5-Mi^7 vs. Ma^6-Mi^8 (3, 12); Ma^5-Mi^7 vs. Ma^6-Mi^9 (56); Ma^6-Mi^5 vs. Ma^2-Mi^2 (19, 32); Ma^6-Mi^5 vs. Ma^7-Mi^2 (14); Ma^6-Mi^5 vs. Ma^2-Mi^{10} (59); Ma^6-Mi^6 vs. Ma^2-Mi^2 (11); Ma^6-Mi^6 vs. Ma^2-Mi^{10} (79); Ma^6-Mi^6 vs. Ma^7-Mi^{10} (76, 85); Ma^2-Mi^7 vs. Ma^6-Mi^9 (71); Ma^3-Mi^2 vs. Ma^6-Mi^3 (50)

Table 3 - Attack and defence patterns in attacks when a goal was scored (Ma = macrostructure; Mi = microstructure).

Goal	Match	Attack (Nº)	Attacking team	Ma attack	Mi Attack	Ma defence	Mi defence
1	2	31	Team A	(4) 4	(3) 4	(4) 4	(4) 4
2[1]	2	60	Team B	(6) 7	(7) 8	(5) 5	(7) 5
3[1,2]	3	6	Team B	(1) 2	(9) 9	(3) 2	(1) 1
4[1,2]	3	33	Team B	(1) 2	(9) 8	(1) 2	(3) 3
5	3	56	Team B	(5) 6	(3) 4	(5) 6	(13) 12
6	4	36	Team A	(1) 3	(3) 9	(1) 4	(1) 5
7	4	44	Team B	(7) 7	(8) 8	(5) 4	(7) 7
8[1,2]	4	65	Team B	(6) 1	(6) 5	(4) 1	(9) 5
9[1,2]	5	19	Team A	(4) 5	(6) 7	(6) 4	(5) 5

[1]Attack pattern performed in that sequence exclusively;
[2]Defence pattern performed in that sequence exclusively. Numbers between parentheses represent the pattern used in the previous attack sequence.

Therefore, it could be inferred that the teams presented structures with different levels of redundancy or diversification. The redundancy has been conceived as the availability or abundance of system resources observed in the microstructure, which reflects its variability[6,18,26]. It results from the relative autonomy of each player. The hierarchy in team sports does not consist in the macrostructure to control the players' individual behaviours in detail but, rather, it constrains how they should interact with each other to form a team[4,16]. The variability of the system's components can also be understood as a kind of compensatory behaviour by the components to maintain collective performance[27].

However, it is important to note that greater variability does not mean redundancy and adaptability[6,28]. For example, in match 1, team A was able to perform a shooting having the microstructure with a single parameter (Ma^3-Mi^1), and it was unable to do it by losing the ball with four ones (Ma^1-$Mi^{1,2,3,4}$). In fact, adaptation depends on the state of the system (for example, functional stability level) as well as the magnitude and type of perturbation[29].

Results also showed that the teams performed more macro-microstructure patterns during attacks than in defences. It is possible that the greatest number of changes in the macro- and/or microstructure in attacks worked as a positive feedback mechanism[4], that is, attacking teams modified their patterns in order to break their couplings with defence. On the other hand, it appeared that the smallest number of changes in the macro- and/or microstructures during defences were enough to work as a negative feedback mechanism by diminishing their discrepancies to the attacks. Similar results were revealed by Yue et al.[30], which found less variation in defence as compared to attack situations. Maybe, the higher variability in defensive structures implies inconsistency rather than flexibility. For example, in match 3 team A presented the highest variability in defence (14 microstructure patterns) and suffered three goals. One could think there might be a balance between consistency and variability so that the system is not highly organised or disorganised for adaptive behaviours to occur[31].

Results also revealed that the teams behaved in a non-sequential way throughout attacks and defences by (1) maintaining their macro- and microstructure, (2) modifying their microstructure only, or, (3) altering their macrostructure. First, this illustrates the dynamic nature of the football game, which results from the simultaneous players' cooperation and opposition t[32]. Second, it shows that consistency and variability are also phenomena observed over the match since teams maintained their structures in some sequences of the game but varied them in other ones. This allows us to infer that the games unfold as a process of formation/maintenance and transformation of structures, therefore, as an adaptive process[4,8]. In addition, results showed that most adaptations throughout the matches occurred by modifying the macrostructures (structural adaptations) rather than the microstructures (parametric adaptations).

To understand the game dynamic, McGarry[33] stressed the need to analyse attack and defence as a relationship, since they only exist in relation to each other. Thus, the second aim of this study was to verify the relation between the attack's macro-microstructure and the defence's macro-microstructure. Results revealed correspondence between them throughout most sequences of the game. In other words, each attack pattern interacted with a corresponding defence pattern in several moments of the game. This indicates that the teams formed a coupling, and it was functional for defensive teams since in most of these sequences the attacking team lost the ball. Therefore, as described previously, defending teams may function effectively based on deviation reduction mechanisms (negative feedback). Evidence of attack-defense coupling was also verified by several studies[9,13,30]. For instance, Moura et al.[13] showed that while the attacking team increased its dispersion, the defending team decreased it.

However, it is important to note that breaks in such couplings have also occurred. This phenomenon has been explained based on the assumption that attacking players functions as a deviation amplifying mechanism (positive feedback)[4,32]. It seems obvious that the number of attacks that resulted in coupling breaks was less in comparison to when teams preserved their stability, otherwise, football would be characterised as a game of dozens of goals[3]. In this regard, similar results have shown that attack-defense coupling is broken at key moments in the game, for example, just before a goal is scored[12].

Concerning the macro-microstructure patterns in the different attack and defence outcomes, the results showed that different patterns led to the same outcome. This highlights that in open systems, a given final state can be achieved in a number of ways[35], similar to the equifinality motor equivalence processes[36]. It is also interesting to note that, on the other hand, different outcomes were reached with the same macro-microstructure pattern. In this case, the inherent flexibility of a team's hierarchical organisation was enough to deal with perturbations generated in such different situations[16]. In a similar vein, Bartlett et al.[9] did not find differences in the players' position and dispersion, either attacking or defending, when four outcomes similar to the present study were considered.

Finally, results showed that the game sequences in which goals were scored involved modifications in relation to the preceding sequence. Such modifications occurred mostly in the macrostructures of both teams. For instance, out of 738 game sequences, only nine (1.22%) resulted in goals. In five of them (goals 2, 3, 4, 8, and 9; Table 3), attacking teams performed completely new interaction patterns between players (macrostructure). Still, out of these, four (goals 3, 4, 8, and 9; Table 3) involved new defence macrostructures. In systemic terms, this set of results allows us to infer that the goal scoring involved novelty/creativity[37,38]. However, the novelty was not beneficial from the point of view of the defensive teams, as it did not make possible the goal to be avoided. According to Tani et al.[8], when a system is perturbed, it might respond by changing the parameters of its components or interaction, or even through the emergence of a completely new structure. On the other hand, the emergent defensive patterns could not reflect a functional and consistent interaction among players[8,39].

Another three goals (5, 6, and 7; Table 3) also involved a reorganisation of the structure (alteration of the macrostructure) of both attacking and defending teams. However, in this case, they were patterns already used in previous attacks/defences. By the end, only one goal (1; Table 3) involved a change in the microstructure. In this case, only parameter modification was enough for the attacking team to achieve the goal, because the defensive team was unable to make any changes. In short, the results showed that most of the goals involved changes in the team's macrostructure, with some of them characterised by novelty.

Finally, the findings of the present study are closed related to its method. As with any scientific procedure, they need to be replicated to give them the power of generalization. Furthermore, further studies should consider dispersion and temporal variables, as well as the ball displacement, to extend the understanding of teams' macro and micro-adaptations.

Conclusion

In summary, the findings of this study allow us to conclude that football teams presented macro-consistency and micro-flexibility; attack and defence coupled their behaviours in most game sequences; teams did not display a relation between patterns and outcome, however, goals were scored after changes in team's structure.

These conclusions imply useful insights to further match analysis and the design of the training process of football teams. According to the results, practitioners and coaches should provide teams with variated and consistent attacking and defending patterns to successfully deal with the demands of the game. Besides, the analysis of football teams as hierarchical systems could be applied in practice to identify the ways football teams modify over the match and use that information as a reference to plan training sessions to prepare for opponents in future matches and provide feedback.

Disclosure statement

The authors report no conflict of interest.

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