ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

ANALYSIS OF THE SIMILARITY OF SURFACE AREA AND SPREAD TIME SERIES BETWEEN OPPONENT FOOTBALL TEAMS.

[1] Felipe Arruda Moura, [2]Luiz Eduardo Barreto Martins, [3]Ricardo Machado Leite de Barros e [3]Sergio Augusto Cunha
[1]State University of Londrina, Laboratory of Applied Biomechanics, Brazil, e-mail: felipearrudamoura@gmail.com.
[2]Campinas State University, Laboratory of Instrumentation for Physiology, Brazil.
[3]Campinas State University, Laboratory of Instrumentation for Biomechanics, Brazil.

SUMMARY

INTRODUCTION

Technology enhancements have led to the development of player-tracking systems that supply player trajectory data. If the 2D coordinates of the players are known, it is possible to understand important features of football dynamics. The team surface area and players spread across the pitch are variables that help describing the organisation of players on the pitch and the interactions between attacking and defending [1].

During a match there is an equilibrium related to players organisation and both teams seek to disturb this equilibrium to create goal-scoring opportunities. In other words, attempts are made to perturb the stability of the opponent system. A perturbation in soccer is defined as an incident that changes the rhythmic flow of attacking and defending, leading to a shooting opportunity [2, 3]. These definitions lead to believe that in the most part of the time, teams have a tactical synchronism and perturbations are able to change it. Therefore, an interesting factor to analyse is whether there is similarity of the surface area and spread time series between opponent teams, once these variables represent players' organization on the pitch.

Therefore, the purpose of this study was to propose an analysis of the similarity of tactical variables time series between professional teams for a description of football match dynamics. A recent study [1] reported that the defending team usually present minor values of surface area and spread compared to the attacking team. Thus, we hypothesized that there is a counter-phase relationship between the surface area and spread time series of opponent teams.

METHODS

We analysed 10 official matches of the Brazilian First Division Championship. The matches were recorded by six digital cameras (30 Hz) from elevated positions in the stadium. After the matches, the images were transferred to computers and were synchronised. We obtained the trajectories of 277 football players over the matches with the automatic tracking methods of DVideo software [4]. Then, we filtered player trajectory with a Butterworth third-order low-pass digital filter with a cut-off frequency of 0.4 Hz. We calculated the team surface area and spread using players coordinates, as function of time.

The team surface area was represented as the area of the convex hull formed by the positions of the teammates. The convex hull of a set of points S on a plane (in our case, represented by each player position, excluding the goalkeeper, at each instant of time t) is the smallest convex set containing S. We computed the team convex hull using the *Quickhull* technique, which is available in the Matlab® software.

For each instant of time t, we calculated the Euclidian distance between each player and his teammates. The distances between players were organised in a symmetric matrix $D(t)$ of order 10 (10 players on a team, excluding the goalkeeper). Given the symmetric matrix $D(t)$, we chose to process the lower triangular matrix $L(t)$ and calculated its Frobenius norm (labelled $\|L\|_F$) to represent the team spread as follows:

$$\|L(t)\|_F = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n}|l_{ij}|^2}$$

To analyse the similarity of the time series, we calculated the cross correlation between the signals. In this study, the cross correlation was applied with a time-lag which varied from -15 to 15 seconds. Finally, we identified the maximal absolute correlation value between the time series and the time-lag associated to this value.

RESULTS AND DISCUSSION

Visual analysis of the time series allows verifying that there is an in-phase similarity between the signals, although with different magnitudes. These results can be confirmed in the figure 1 that presents the results of the cross correlation as function of the time-lag for the first half. It is possible to verify that the greatest correlation values are positive and they are associated to low time-lags. Table 1 summarizes the results of the cross correlation analysis for both variables and halves, with the maximal correlation (CC) and the time-lag values associated (TL).

Usually, football teams present greater surface area and spread when they have ball possession than when they are defending [1, 5]. For this reason, our initial assumption was that there was a counter-phase relationship between teams time series, i.e., when the value of a given variable of one of

the teams increases, the opponent value would decrease and vice-versa. However, this hypothesis was not confirmed because the cross correlation presented positive values, showing that teams may have an in-phase synchronism for these variables during a great part of the match period.

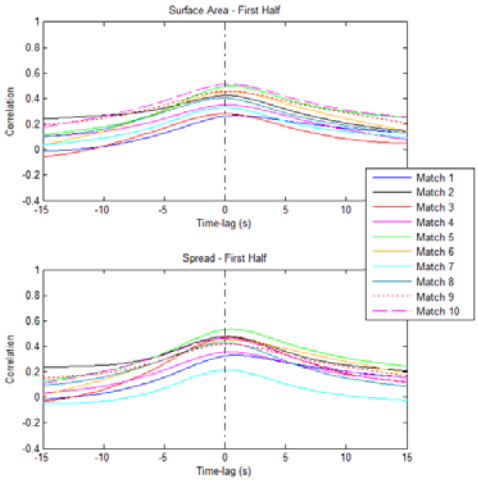

Figure 1: Correlation values between teams time series, as function of the time-lag.

These data do not corroborate the Yue and colleagues study [5] that presented a counter-phase relationship in the spread time series using visual analysis. For the teams surface area during small-sided games, a recent research [6] reported Pearson correlation varying from 0.01 to 0.07. These values are different from those found in this study, probably justified by the fact that these authors examined smalls-sided games and not official professional matches.

The cross correlation analysis also allowed verifying that there is a time-lag of tenths of a second between the signals, showing an interaction between adversary teams. Previous studies have attempted to find in team sports some features of dynamics systems that present global patterns of behaviour [6, 7]. Noting that in the present study teams time series have synchronism with low time-lag, these results may indicate the presence of this pattern. Furthermore, if the behaviour of a given team is similar to the opponent, this information can be used by coaches in order to 'guide' the collective behaviour of the adversary.

CONCLUSIONS

This study sought to analyse the surface area and spread time series of opponent football teams in order to describe players organization dynamics during an official match. Specifically, we analysed the similarity between the teams time series using cross correlation. For the match analysed, results allowed to conclude that time series have a tendency of presenting an in-phase synchronism with low time-flag. Further studies should investigate if goal-scoring is associated to a lack of synchronism between time-series, according to the perturbation theory cited in literature.

REFERENCES

1. Moura, F.A., et al., *Quantitative analysis of Brazilian football players' organisation on the pitch.* Sports Biomechanics, 2012. **11**(1): p. 85-96.
2. Frencken, W.G.P. and K.A.P.M. Lemmink, *Team kinematics of small-sided soccer games*, in *Science and Football VI*, T. Reilly and F. Korkusuz, Editors. 2009, Routledge: New York. p. 161-166.
3. Hughes, M., et al., *The perturbation effect and goal opportunities in soccer.* Journal of Sports Sciences, 1998(16): p. 20.
4. Figueroa, P.J., N.J. Leite, and R.M.L. Barros, *Tracking soccer players aiming their kinematical motion analysis.* Computer Vision and Image Understanding, 2006. **101**(2): p. 122-135.
5. Yue, Z., et al., *Mathematical Analysis of a Soccer Game. Part I: Individual and Collective Behaviors.* Studies in Applied Mathematics, 2008. **121**(3): p. 223-243.
6. Frencken, W., et al., *Oscillations of centroid position and surface area of soccer teams in small-sided games.* European Journal of Sport Science, 2011. **11**(4): p. 215-223.
7. McGarry, T., et al., *Sport competition as a dynamical self-organizing system.* J Sports Sci, 2002. **20**(10): p. 771-81.

Table 1. Results of cross correlation between the time series of opponent teams.

Match	Surface Area				Spread			
	1st Half		2nd Half		1st Half		2nd Half	
	CC	TL (s)	CC	TL (s)	CC	TL (s)	CC	TL (s)
Match 1	0.27	0.93	0.35	0.00	0.33	0.93	0.33	0.00
Match 2	0.42	0.13	0.58	0.40	0.48	0.13	0.43	0.00
Match 3	0.28	0.00	0.07	0.00	0.47	0.27	0.02	0.13
Match 4	0.35	0.13	0.30	0.00	0.36	0.40	0.35	0.00
Match 5	0.50	0.53	0.54	0.40	0.53	0.53	0.51	0.13
Match 6	0.46	0.40	0.47	0.40	0.45	0.67	0.40	0.27
Match 7	0.33	0.00	0.48	0.27	0.22	0.13	0.48	0.13
Match 8	0.40	0.13	0.53	0.00	0.43	0.00	0.32	0.00
Match 9	0.46	0.27	0.47	0.27	0.42	0.27	0.38	1.20
Match 10	0.51	0.40	0.35	0.80	0.46	0.00	0.40	0.27
Mean ± SD	0.40 ± 0.08	0.29 ± 0.29	0.41 ± 0.15	0.25 ± 0.26	0.41 ± 0.09	0.33 ± 0.30	0.36 ± 0.13	0.21 ± 0.36

* CC = maximal absolute correlation; TL = time-lag values associated to CC.