Fatigue in soccer: NEW APPROACHES AND CONCEPTS. SPAIN PERSPECTIVE

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Today's talk

- Fatigue in soccer. Traditional concepts and approaches
- The influence of situational variables on distance covered in soccer
- The future of performance analysis
- Conclusions

Fatigue in soccer

Journal of Sports Sciences, June 2005; 23(6): 593 – 599

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Fatigue in soccer: A brief review

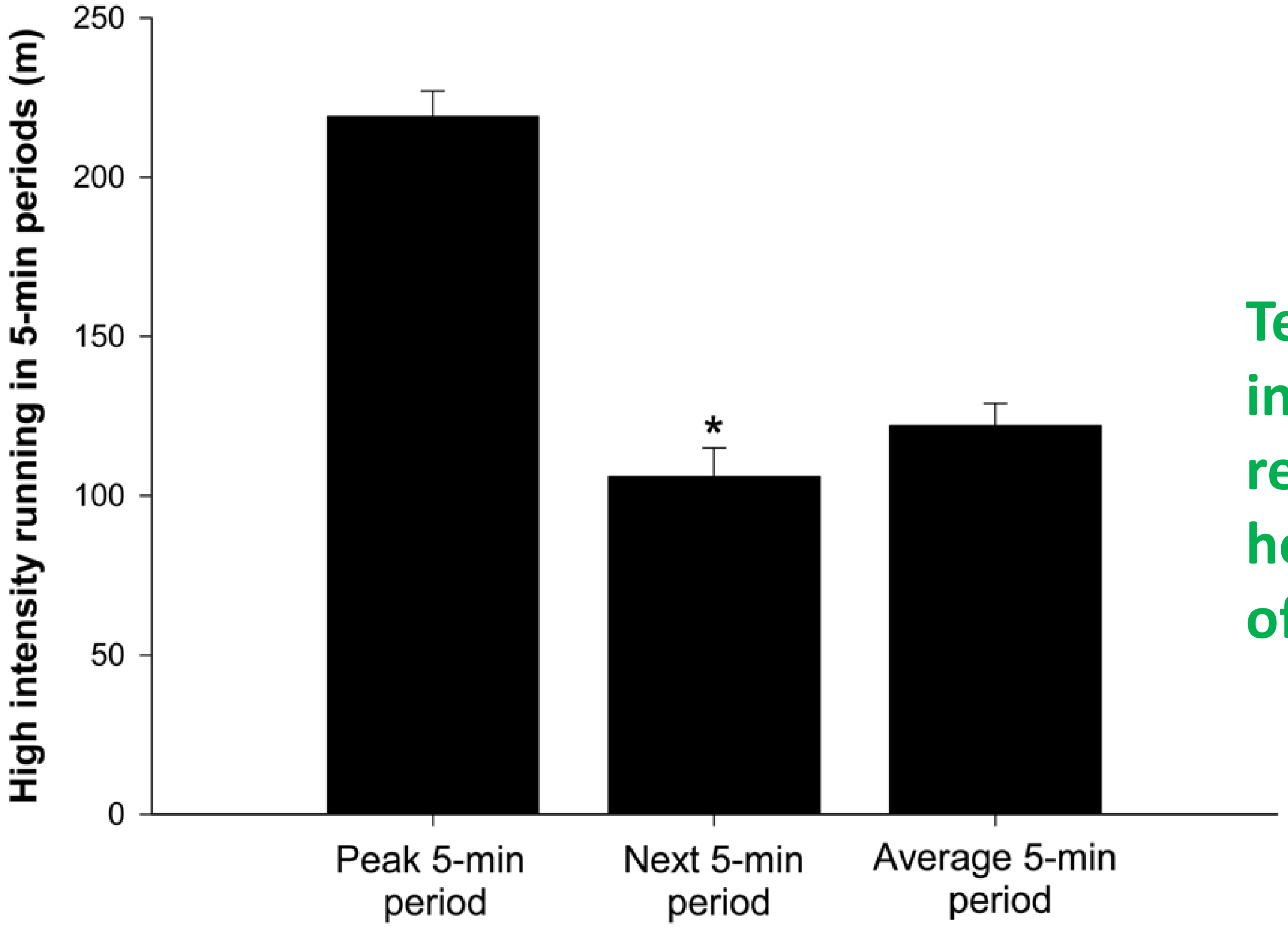
MAGNI MOHR, PETER KRUSTRUP, & JENS BANGSBO

Institute of Exercise and Sport Sciences, Department of Human Physiology, August Krogh Institute, University of Copenhagen, Copenhagen, Denmark

According to time – motion analyses and performance measures during match-play, fatigue or reduced performance seems to occur at three different stages in the game:

- after short-term intense periods in both halves;
- in the initial phase of the second half; and
- towards the end of the game.

after short-term intense periods in both halves…

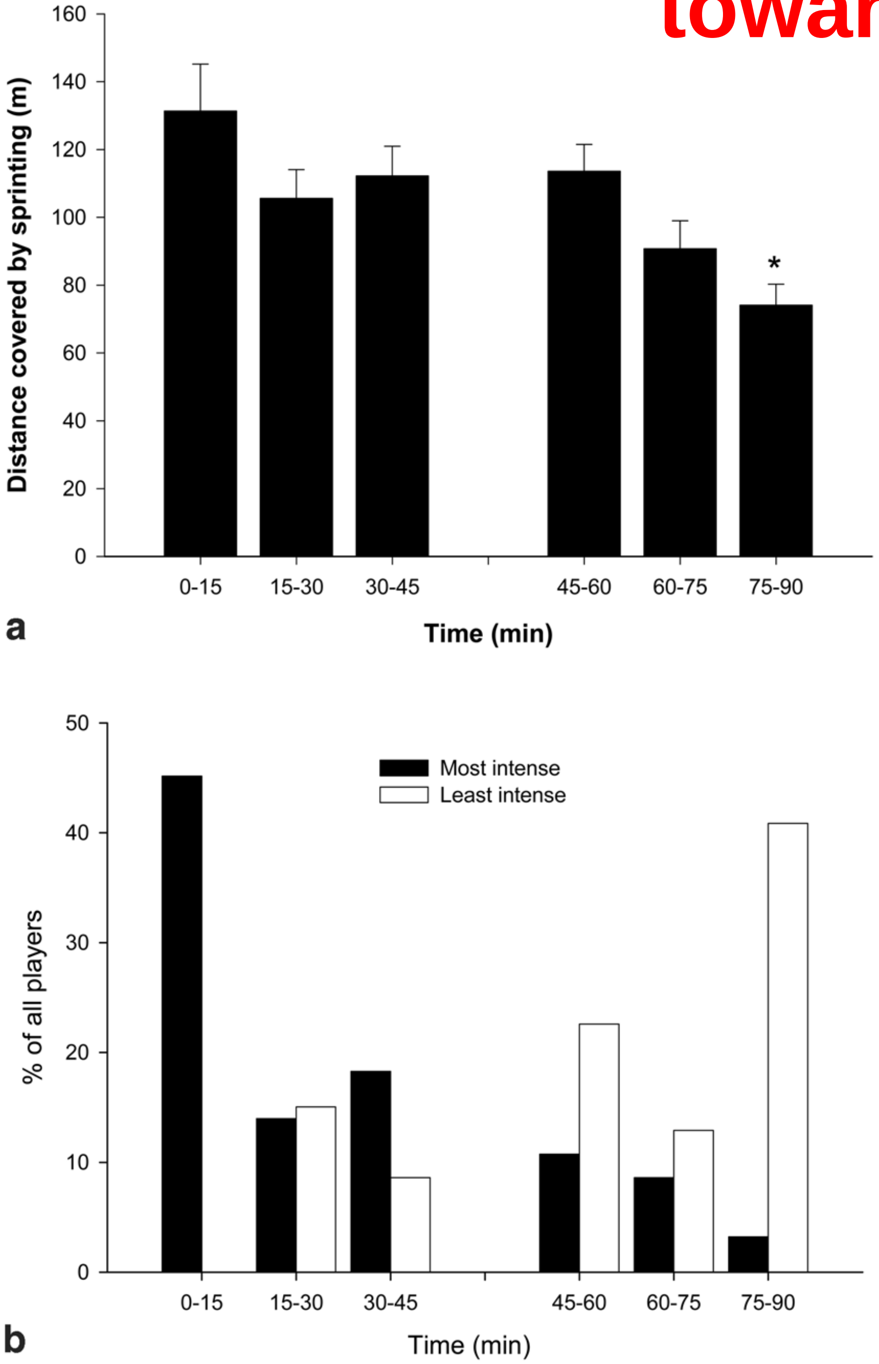


Temporary fatigue after periods of intense exercise in the game, it may be related to disturbances in muscle ion homeostasis and an impaired excitation of the sarcolemma

High-intensity running in the most intense 5-min period during the game, the following 5-min period as well as the game average for elite players during competitive matches (n = 18).

*** Significant difference between the 5-min period immediately after the most intense period during the game and the game average (data from Mohr et al., 2003a).**

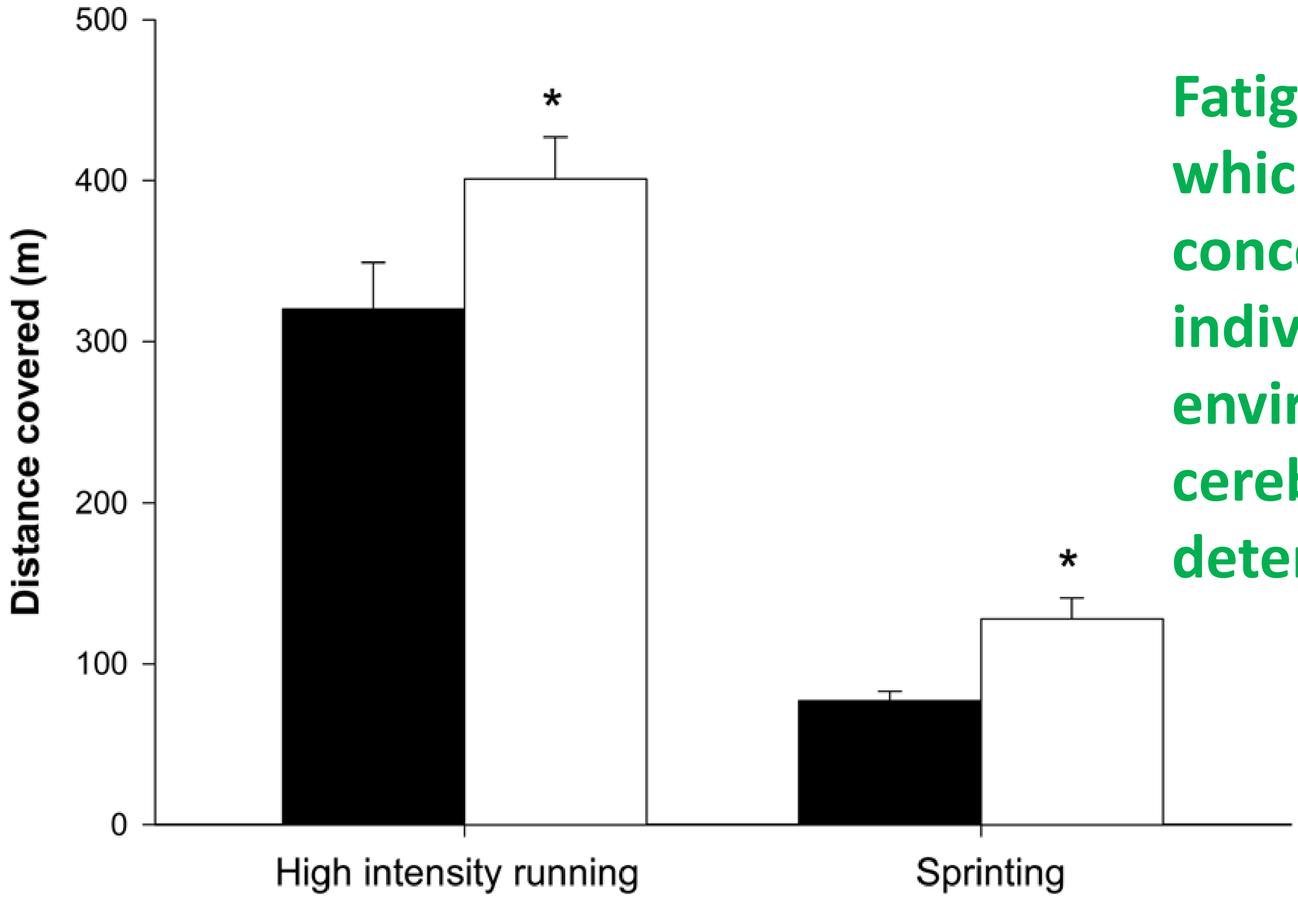
towards the end of the game…. 1/2



Distance covered by sprinting during 15-min periods throughout competitive soccer games at the highest international level (A, n = 18) and distribution of 15-min intervals with the most and least intense running for elite players during competitive matches (B, n = 93).

*** Significant difference from the first four 15-min periods of the game (modified from Mohr et al., 2003a).**

towards the end of the game.... 2/2

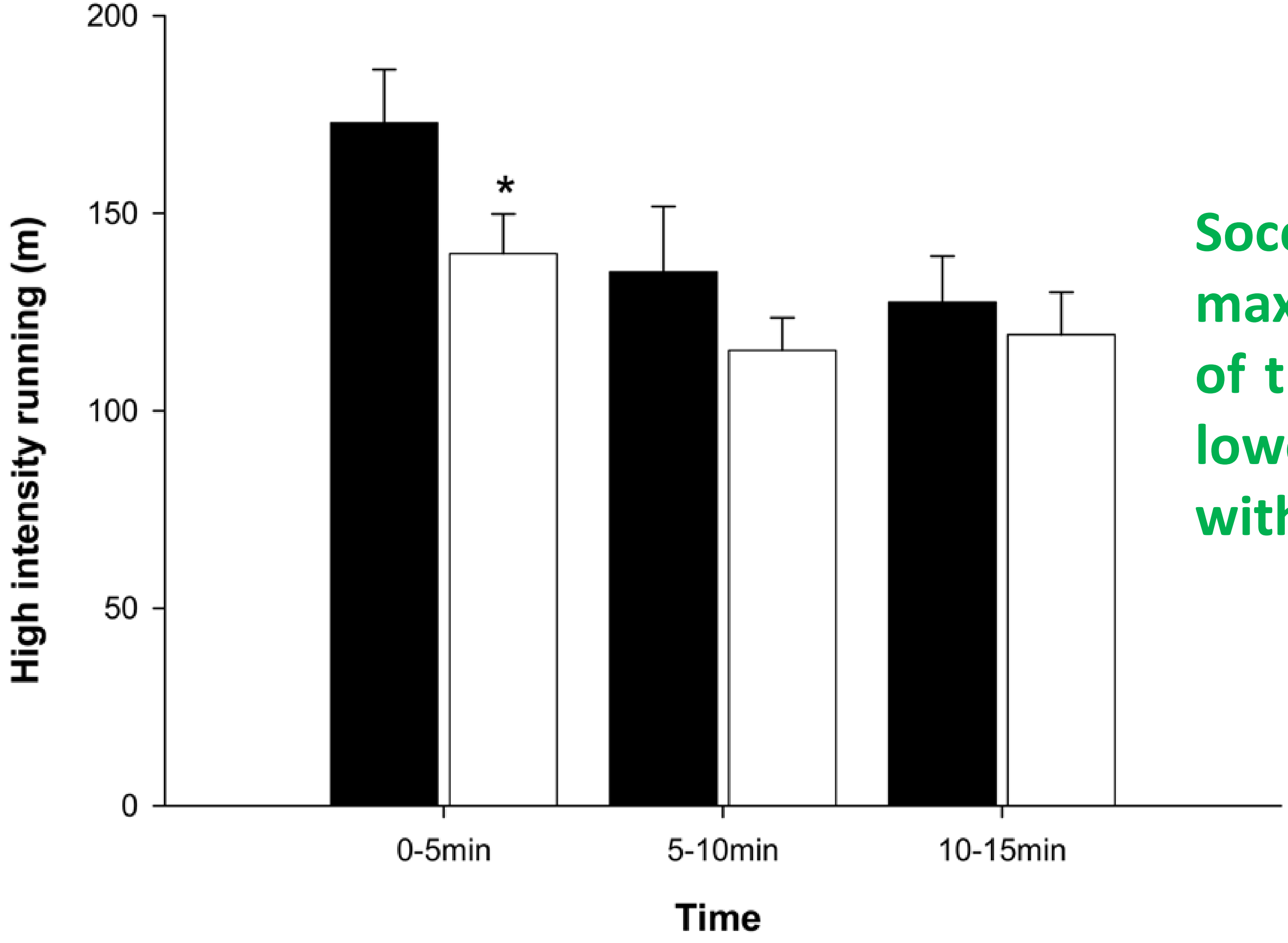


Fatigue sets in towards the end of a game, which may be caused by low glycogen concentrations in a considerable number of individual muscle fibres. In a hot and humid environment, dehydration and a reduced cerebral function may also contribute to the deterioration in performance

High-intensity running and sprinting during the final 15 min of a game by players participating in the entire game and substitutes only participating in the second half.

***Significant difference between substitutes and players participating in the entire game (data from Mohr et al., 2003a).**

in the initial phase of the second half…



Soccer players' ability to perform maximally is inhibited in the initial phase of the second half, which may be due to lower muscle temperatures compared with the end of the first half.

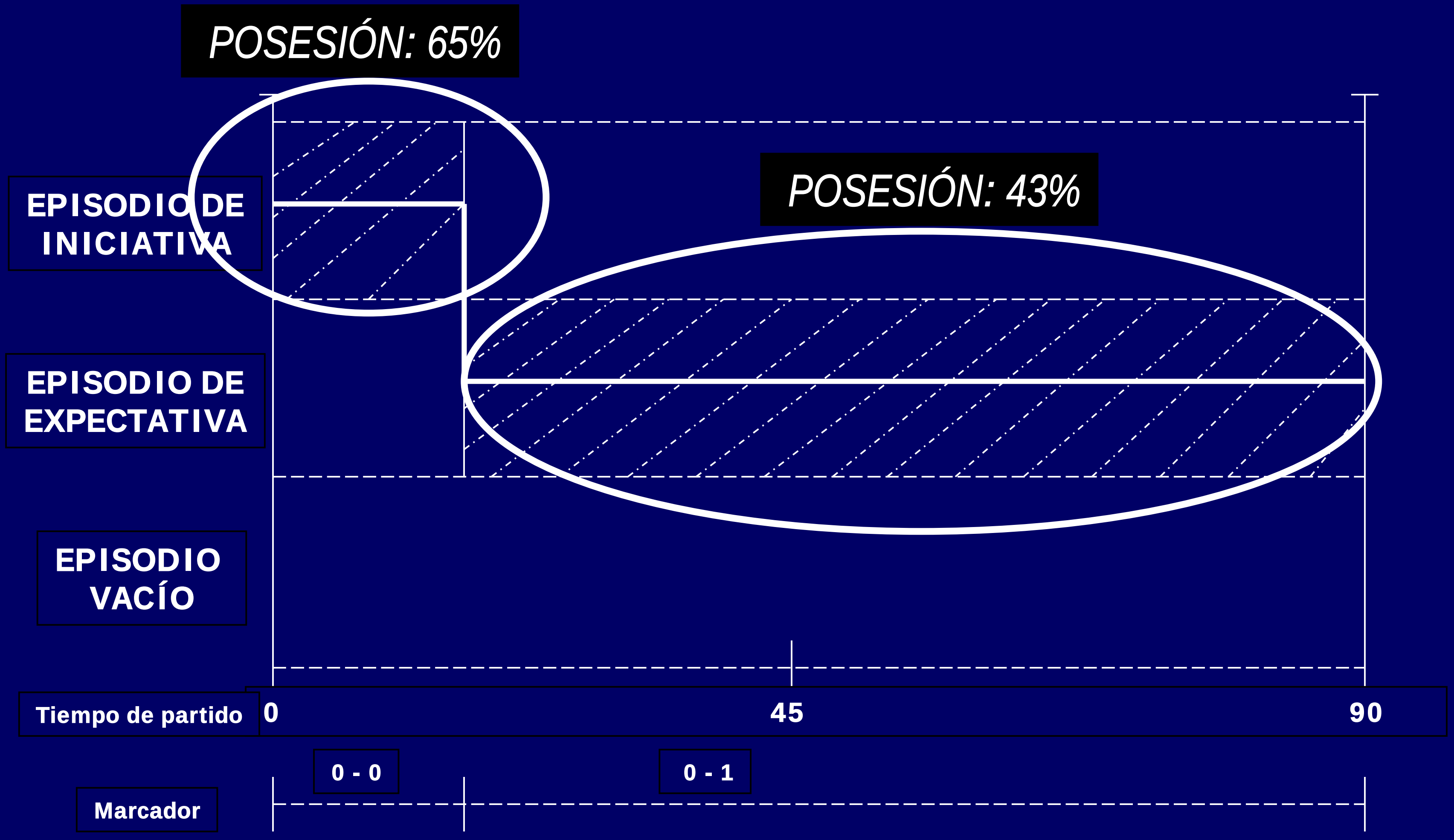
High-intensity running by elite soccer players during the initial phase of the first and second halves of competitive games (n = 42).

* Significant difference between the two halves .

Statistics Deportivo vs F.C. Barcelona Season 2004-2005

DEPORTIVO		F.C. BARCELONA
54%	Posesión del balón	46%
3	Remates portería	5
14	Remates fuera	11
49	Centros al área	12
0	Goles	1

Performance Profile F.C. Barcelona
Match Deportivo-F.C. Barcelona Season 2004-2005.



Performance Profile F.C. Barcelona INITITIATIVE ESPISODE Match Deportivo-F.C. Barcelona Season 2004-2005.

DEPORTIVO		F.C. BARCELONA
35%	Posesión del balón	65%
0	Remates portería	3
2	Remates fuera	4
2	Centros al área	2
0	Goles	1

Comparison of total distance covered by elite soccer players during the first and second halves of competitive match-play

Study	Nationality	System	Distance run (m)			Difference %
			Total	1st half	2nd half	
Bradley et al. [14]	English	ProZone	10714	5422	5292	-2.4
Bradley et al. [15]	English	ProZone	10842	5469	5372	-1.8
Carling et al. [16]	French	Amisco Pro	11126	5694	5432	-5.9
Castellano et al. [11]	Spanish	Amisco Pro	7829 *	3871 *	3958 *	+2.2
Di Salvo et al. [2]	European	Amisco Pro	11393	5709	5684	-0.4
Lago et al. [12]	Spanish	Amisco Pro	10943	5503	5440	-1.2
Rampinini et al. [7]	Italian	SICS	11828	5966	5862	-1.7
Zubillaga et al. [13]	English	Amisco Pro	10549	5297	5252	-0.9
	Spanish	Amisco Pro	10339	5121	5218	+1.9

*Distance covered by players in each half during the *effective playing time*.

... non-conclusive ¡¡¡¡

Comparison of distance covered at maximal intensity by elite soccer players during the first and second halves of competitive match-play

Study	Category of movement	Nationality	System	Distance run (m) total	1st half	2nd half	Difference %
Bradley et al. [15]	>25.1km.h^{-1}	English	ProZone	255	123	132	+6.8
Carling et al. [16]	>22.0 km.h^{-1}	French	Amisco Pro	337	165	172	+4.2
Castellano et al. [11]	>24.0 km.h^{-1}	Spanish	Amisco Pro	223	116*	107*	-8.4
Di Salvo et al. [2]	>25.1km.h^{-1}	English	ProZone	226	114	112	-1.8
Lago et al. [12]	>23.0 km.h^{-1}	Spanish	Amisco Pro	284	137	147	+6.8
Zubillaga et al. [13]	>21.0 km.h^{-1}	English	Amisco Pro	410	202	208	+2.9
		Spanish	Amisco Pro	460	194	266	+27.1

*Distance covered by players in each half during the *effective playing time*.

… non-conclusive ¡¡¡¡

Analysis of physical activity profiles in elite soccer. The case of Real Madrid

One hundred and forty-nine matches including league, cup and UEFA Champions League played by the Real Madrid were monitored during the 2001-2002 to the 2006-2007 seasons (six seasons).

Data from both teams (Real Madrid and the opponent) were recorded. The players included in the study met two basic criteria: (1) completing the entire match (at least in three matches of the whole sample), and (2) because the physical loading of goalkeepers differs from that of field players, they were not included in the study.

Altogether, 2082 physical performance profiles were examined, 1052 from the Real Madrid and 1031 from the opposing team (Central Defenders (CD) = 536, External Defenders (ED) = 491, Central Midfielders (CM) = 544, External Midfielders (EM) = 233, and Forwards (F) =278). km/h (Sprint), and the number of sprints (21.1-24.0 km/h and >24.0 km/h).

Miñano (2015)

Analysis of physical activity profiles in elite soccer. The case of Real Madrid

Differences in the distance covered between Real Madrid and the opposing team in High-Intensity Running (21.1-24.0 km/h) depending on the player's position.

	Real Madrid	Opposing Team	η^2
Playing Position			
External Defenders (ED)	340 (± 90)	341 (± 100)	.000
Central Defenders (CD)	180 † (± 65)	192 (± 74)	.007
Central Midfielders (CM)	253 ‡ (± 87)	284 (± 96)	.029
External Midfielders (EM)	354 ‡ (± 88)	382 (± 109)	.019
Forwards (F)	269 ‡ (± 86)	297 (± 103)	.022
Mean	269† (± 104)	285 (± 114)	.011

‡Significantly lower than the opposing team ($p<0.01$).
†Significantly lower than the opposing team ($p<0.05$).

Players from Real Madrid covered lower distances ($p<0.05$) in HIR than players from the opposing team (Table 1). While ED did not show differences in their physical performance, CD ($p<0.05$), CM ($p<0.01$), EM ($p<0.01$) and F ($p>0.01$) from Real Madrid covered lower distances in HIR than their counterparts (180 v. 192, 257 v. 284, 354 v. 382 and 269 v. 297, respectively).

Miñano (2015)

Analysis of physical activity profiles in elite soccer. The case of Real Madrid

Differences in the distance covered between Real Madrid and the opposing team in Sprint (>24.0 km/h) depending on the player's position.

	Real Madrid	Opposing Team	η^2
Playing Position			
External Defenders (ED)	374 ↑ (± 144)	320 (± 143)	.034
Central Defenders (CD)	161 (± 91)	164 (± 87)	.000
Central Midfielders (CM)	179 (± 95)	196 (± 113)	.006
External Midfielders (EM)	320 † (± 132)	361 (± 158)	.020
Forwards (F)	235 ‡ (± 99)	306 (± 138)	.081
Mean	245‡ (± 141)	248 (± 145)	.004

↑ Significantly higher than the opposing team ($p<0.05$).
‡Significantly lower than the opposing team ($p<0.01$).
†Significantly lower than the opposing team ($p<0.05$).

Players from Real Madrid players covered lower distances in Sprint (p<0.05) than players from the opposing team (Table 2). While CD and CM did not show differences in their physical performance, EM (p<0.05) and F (p>0.01) Real Madrid players covered lower distances in sprint than their counterparts (320 v. 361, 235 v. 306, respectively). However, ED from Real Madrid covered higher distances than their counterparts (374 v. 320, p<0.05).

Miñano (2015)

Possible relationship between the true explanation and the estimated explanation

		True Model	
		$Y = \beta_1 + \beta_2 X_2 + \mu$	$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \mu$
Estimated Model	$Y = b_1 + b_2 X_2$	Correct 1	**Bias** 2
	$Y = b_1 + b_2 X_2 + b_3 X_3$	**Inefficiency** 3	Correct 4

DIAPOS SOBRE SESGO: King, keohane y verba

An Example of **BIAS**…

```
. reg  velocid sj cmj edad

      Source |       SS       df       MS              Number of obs =     282
-------------+------------------------------           F(  3,   278) =  176.10
       Model |  15.8426506     3  5.28088352           Prob > F      =  0.0000
    Residual |  8.33686752   278  .029988732           R-squared     =  0.6552
-------------+------------------------------           Adj R-squared =  0.6515
       Total |  24.1795181   281  .086048107           Root MSE      =  .17317

------------------------------------------------------------------------------
     velocid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sj |  -.0081313   .0036244    -2.24   0.026     -.015266   -.0009966
         cmj |  -.0207848   .0035434    -5.87   0.000    -.0277602   -.0138095
        edad |  -.0698032   .0064917   -10.75   0.000    -.0825823   -.0570242
       _cons |   6.617306   .0934596    70.80   0.000     6.433328    6.801284
------------------------------------------------------------------------------
```

but…

…this is the correct model

```
. xi: reg  velocid sj cmj_b talla edad i.puesto
i.puesto          _Ipuesto_1-6        (naturally coded; _Ipuesto_1 omitted)

      Source |       SS       df       MS              Number of obs =     279
-------------+------------------------------           F(  9,   269) =   81.84
       Model |  17.5575844     9  1.95084271           Prob > F      =  0.0000
    Residual |  6.41242564   269  .023838014           R-squared     =  0.7325
-------------+------------------------------           Adj R-squared =  0.7235
       Total |    23.97001   278  .086223058           Root MSE      =   .1544

------------------------------------------------------------------------------
     velocid |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
          sj |  -.0067641   .0027603    -2.45   0.015    -.0121988   -.0013295
       cmj_b |   -.022579   .0024843    -9.09   0.000    -.0274702   -.0176878
       talla |  -.0066296   .0014494    -4.57   0.000    -.0094833    -.003776
        edad |  -.0428683   .0072433    -5.92   0.000    -.0571291   -.0286075
  _Ipuesto_2 |  -.0869996   .0373218    -2.33   0.020    -.1604795   -.0135197
  _Ipuesto_3 |  -.0631956   .0365571    -1.73   0.085      -.13517    .0087789
  _Ipuesto_4 |    -.05833   .0361893    -1.61   0.108    -.1295803    .0129204
  _Ipuesto_5 |  -.0956032   .0392951    -2.43   0.016    -.1729682   -.0182381
  _Ipuesto_6 |  -.0956522   .0354724    -2.70   0.007     -.165491   -.0258134
       _cons |   7.562476   .1973691    38.32   0.000     7.173892    7.951061
------------------------------------------------------------------------------
```

MATCH STATUS

Performance accomplishments are a powerful source of efficacy expectations and such expectations determine the task-related effort that has to be expended (Bandura, 1977). Match status may be viewed as a measure of performance accomplishments and hence may influence the effort made by a player (O'Donoghue and Tenga, 2001).

Match status is determined by whether a team or a player is winning, losing or drawing at the time a particular behaviour is recorded (Bloomfield et al., 2005a, 2005b; Jones et al., 2004; Taylor et al., 2008). According to Bloomfield et al. (2005a), Lago and Martin (2007) and Taylor et al. (2008), the importance of this situational variable is reflected in changes in team and player's strategies in response to the score-line. For low-scoring team sports like soccer or rugby, there are just three major levels of match status to be considered during analysis (team winning, losing or drawing).

Journal of Sports Sciences, 2001; 19(1): 25-26

BASES 2000: Back to the future

The effect of score-line on work rate in elite soccer

P.G. O'Donoghue[1] and A. Tenga[2]

[1]*School of Leisure and Tourism, The University of Ulster at Jordanstown, Newtownabbey, Co. Antrim BT37 0QB, UK and* [2]*Norwegian University of Sports and Physical Education, Oslo, Norway*

Table 1. Distribution of match time among different activities (mean ± *s*)

	Group A (n = 11)		Group B (n = 10)	
Activity	Level	Ahead	Level	Behind
Stationary	10.8 ± 2.9	13.8 ± 5.4	11.0 ± 4.9	12.6 ± 3.3
Walking	40.2 ± 7.8	42.7 ± 9.0	38.4 ± 5.3	41.1 ± 5.2
Backing	7.8 ± 3.1	7.2 ± 3.2	8.1 ± 2.5	8.6 ± 2.2
Jogging	28.2 ± 5.2	25.1 ± 6.1	28.1 ± 7.8	26.0 ± 6.7
Running	3.4 ± 1.7	2.8 ± 1.3	3.5 ± 1.8	2.7 ± 1.5
Shuffling	7.3 ± 2.5	6.2 ± 2.3	8.5 ± 1.9	6.5 ± 1.3
Football	2.3 ± 0.8	2.3 ± 0.8	2.3 ± 1.2	2.4 ± 1.1
High-intensity activity	13.0 ± 1.7	11.2 ± 1.7	14.3 ± 2.6	11.6 ± 2.0

Players performed significantly less high-intensity activity when winning than when the score was level ($z = 2.45$, $P < 0.05$). Players also performed significantly less high intensity activity when losing than when the score was level ($z = 2.70$, $P < 0.01$). Players on teams that are winning relax their work-rate, allowing opponents back into the game, and that players on teams that are trailing may lose the motivation to maintain a sufficient work-rate.

The effects of situational variables on distance covered at various speeds in elite soccer

European Journal of Sport Science
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http://www.informaworld.com/smpp/title~content=t714592354

The effects of situational variables on distance covered at various speeds in elite soccer

Carlos Lago [a]; Luis Casais [a]; Eduardo Dominguez [a]; Jaime Sampaio [b]
[a] Facultad de CC da Educacion e o Deporte, Universidad de Vigo, Pontevedra, Spain [b] Department of Sport Sciences, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

Online publication date: 08 February 2010

Variables	14.1.-19 km/h	19.1 – 23 km/h	>23 Km/h
Playing positions			
Full Back	294 (55.3)**	189 (26.3)**	140 (24.0)**
Central Midfielder	459 (64.5)**	112 (24.5)**	-10.5 (16.4)
Wide Midfielder	482 (71.7)**	214 (45.7)**	147.1(34.4)**
Forward	122 (75.2)	190 (28.4)**	149.7 (24.1)**
Match status			
Drawing	0.40 (1.09)	-1.20 (0.45)**	-0.34 (0.41)
Winning	-0.05 (0.96)	-0.83 (0.42)*	-0.71 (0.30)*
Match location	-23.87 (47.1)	-27.7 (20.3)	-27.3 (16.5)
Quality of opponent	0.87 (4.94)	3.11 (2.18)	0.76 (1.69)
Intercept	1436 (87.8)**	485 (37.7)**	231.2 (30.7)**
Obervations	182	182	182
R^2	0.30	0.34	0.38

Notes: The values are the number of metres covered by players in a match. ** (*P* < 0.01) * (*P* < 0.05)

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Online publication date: 08 February 2010

Simulated distance covered (m) at different speeds depending on the match location, quality of opposition and match status

		Home matches						Away matches					
Match Status	Quality of opposition	Total	0-11 Km/h	11.1 - 14 km/h	14.1-19 km/h	19.1-23 km/h	>23 km/h	Total	0-11 km/h	11.1 - 14 km/h	14.1-19 km/h	19.1-23 km/h	>23 km/h
Winning 90 min	Strong	11140	7050	1744	1649	481	217	10856	6911	1584	1653	453	189
Winning 90 min	Weak	10824	6727	1662	1665	540	231	10540	6587	1501	1669	512	204
Losing 90 min	Strong	10856	6853	1678	1653	555	281	10641	6713	1518	1629	527	253
Losing 90 min	Weak	10540	6529	1596	1669	614	295	10325	6390	1435	1646	586	268

Contextual Variables and Time-Motion Analysis in Soccer

Authors J. Castellano[1], A. Blanco-Villaseñor[2], D. Álvarez[1]

Affiliations [1] Basque Country University, Physical Activity and Sport, Vitoria-Gasteiz, Spain
[2] Barcelona University, Methodology of the Behavioural Sciences, Barcelona, Spain

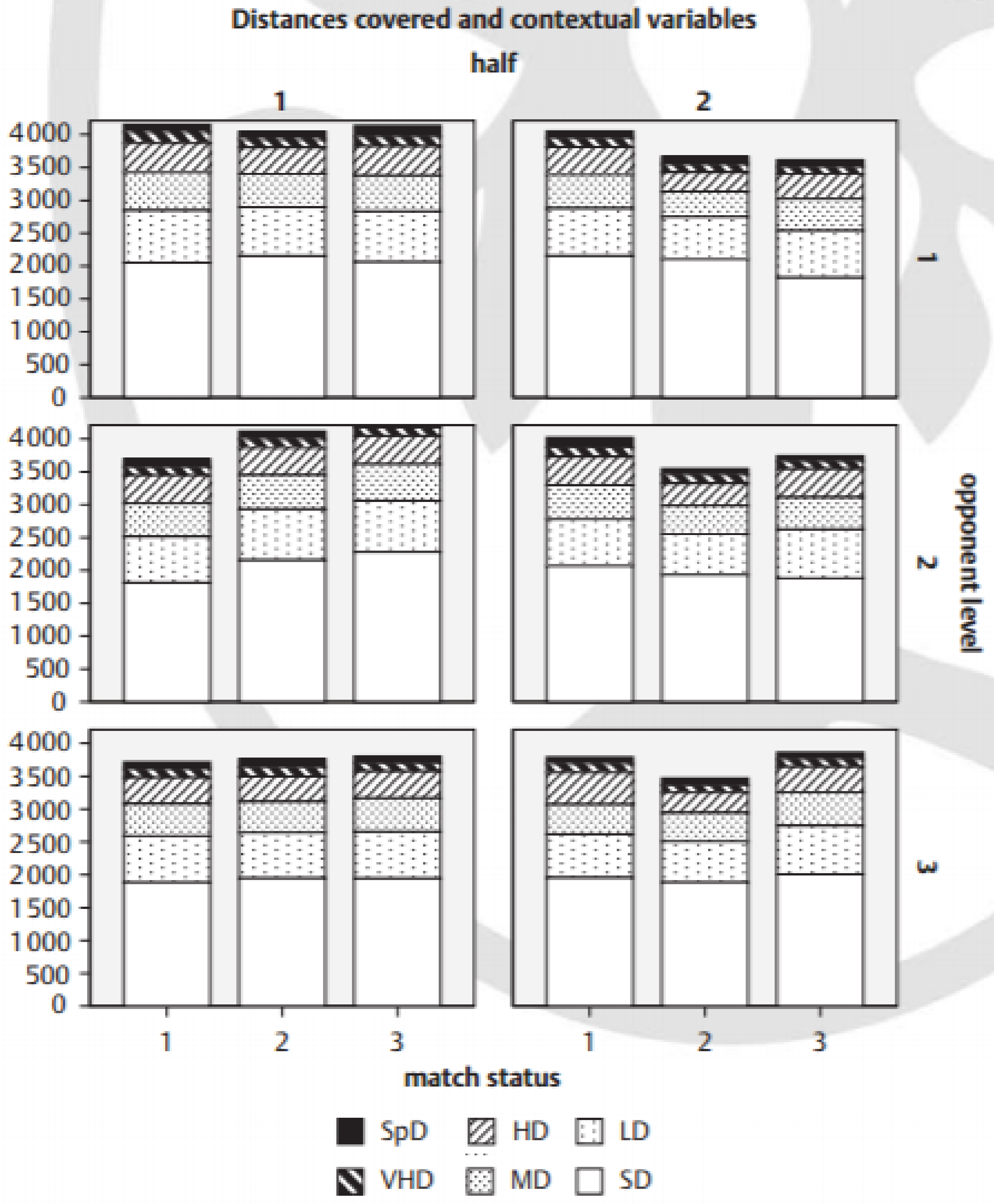

Fig. 1 Distances covered and contextual variables. Running intensities are: SD (0–11 Km · h^{-1}); LD (11.1–14 Km · h^{-1}); MD (14.1–17 Km · h^{-1}); HD (17.1–21 Km · h^{-1}); VHD (21.1–24 Km · h^{-1}); and SpD (>24 Km · h^{-1}). *Opponent level* was Top (1), Medium (2) and Bottom (3). *Halves* were First (1) and Second (2). *Match status* was Lose (1), Draw (2) and Win (3).

Distances covered (Spd, VHD, HD and MD) by the reference team were greater when the result was adverse. This suggests that when losing, players try to reach their maximal physical capacity in order to draw or win the match. Accordingly, players clearly performed less low-intensity activity.

Match Status: concluding remarks

These results suggest that players **DO NOT ALWAYS USE THEIR MAXIMAL PHYSICAL CAPACITY DURING THE MATCH.** In fact, given that winning is a comfortable state for a team, it is possible that players assume a ball retention strategy, slowing down the game and resulting in lower speeds (Bloomfield et al., 2005b). On the other hand, when losing, players try to reach their maximal activity in order to win or draw the match. Other studies have considered match status in relation to the tactical aspects of performance. The influence of this factor is reflected in changes in team strategies and tactics as a response to match situations (Taylor et al., 2008). Teams often show a more defensive strategy when winning than when losing, and vice versa.

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The influence of match location, quality of opposition, and match status on possession strategies in professional association football

Carlos Lago [a]
[a] Facultad de CC da Educacíon e o Deporte , Universidad de Vigo , Pontevedra, Spain
Published online: 15 Sep 2009.

Time spent in different zones of play by the ball depending on match location and match status.

	Playing at Home			Playing away		
Match status	Defensive third	Middle third	Attacking third	Defensive third	Middle third	Attacking third
Winning	27.5	51.7	19.1	34.6	48.8	12.9
Losing	17.2	57.0	25.5	24.3	54.1	21.6
Drawing	20.2	56.1	23.2	27.3	53.2	19.3

Overall, there was more play in the attacking zone when Espanyol was playing at home than playing away. Moreover, when behind, possession was less in the defensive zone and more in the attacking zone than when the team was winning or drawing

Journal of Sports Sciences

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Published online: 15 Sep 2009.

. Simulated possession for the team depending on *match location*, *quality of opposition*, and *match status*.

	Playing at home					Playing away				
Opposition Status	Real Madrid (2nd)	Sevilla (5th)	Betis (9th)	Athletic (12th)	Real Sociedad (16th)	Real Madrid (2nd)	Sevilla (5th)	Betis (9th)	Athletic (12th)	Real Sociedad (16th)
Winning	39.0	39.5	40.3	40.9	41.6	33.0	35.3	38.3	40.5	42.4
Drawing	46.9	47.5	48.2	48.8	49.6	41.0	43.2	46.2	48.5	50.4
Losing	49.2	50.5	51.3	51.8	52.6	44.0	46.3	49.3	51.5	53.3

QUALITY OF OPPOSITION

The opponent level has been considered from different methodological perspectives.

For example, teams and players have been categorized as ‘successful’ and ‘unsuccessful’ according to their standings within a particular tournament (Grant et al., 1999), or classified as ‘strong’ or ‘weak’ based on symmetric division of end-of-season classification (O’Donoghue et al., 2008; Taylor et al., 2008).

Lago et al. (2010) defined the quality of opposition as the differences in the end-of-season ranking between opposing teams.

Recently, team performance has been classified using cluster analysis procedures, which improve the classification by using more valid cut-off values (Sampaio et al., 2010a Marcelino et al., 2011).

Table 1. Total distance covered (m) and distance covered at several intensities by opposition level.

	Against 1st League (1^{st})	Against 2nd League (2^{nd})	Against amateurs (am)	Pairwise comparison
Total distance covered (m)	5395.3±588.6	5069.7±527.5	5407.9±597.3	
Distance covered at				
Low intensity (0.0–3.5 km · h^{-1})	422.2±67.0	436.9±67.2	399.8±91.1	
Moderate intensity (3.6–14.3 km · h^{-1})	3655.2±299.5	3615.1±332.3	3896.7±454.3	1^{st}<am*; 2^{nd}<am*
High intensity (14.4–19.7 km · h^{-1})	910.9±306.5	729.3±267.1	807.0±257.1	
Very high intensity (>19.8 km · h^{-1})	407.1±193.9	288.4±135.2	304.4±140.2	1^{st}>2^{nd}, am*

* Significant differences at $p<0.05$.

doi:10.1371/journal.pone.0097145.t001

Folgado H, Duarte R, Fernandes O, Sampaio J (2014) Competing with Lower Level Opponents Decreases Intra-Team Movement Synchronization and Time-Motion Demands during Pre-Season Soccer Matches. PLoS ONE 9(5): e97145. doi:10.1371/journal.pone.0097145
http://www.plosone.org/article/info:doi/10.1371/journal.pone.0097145

Contextual Variables and Time-Motion Analysis in Soccer

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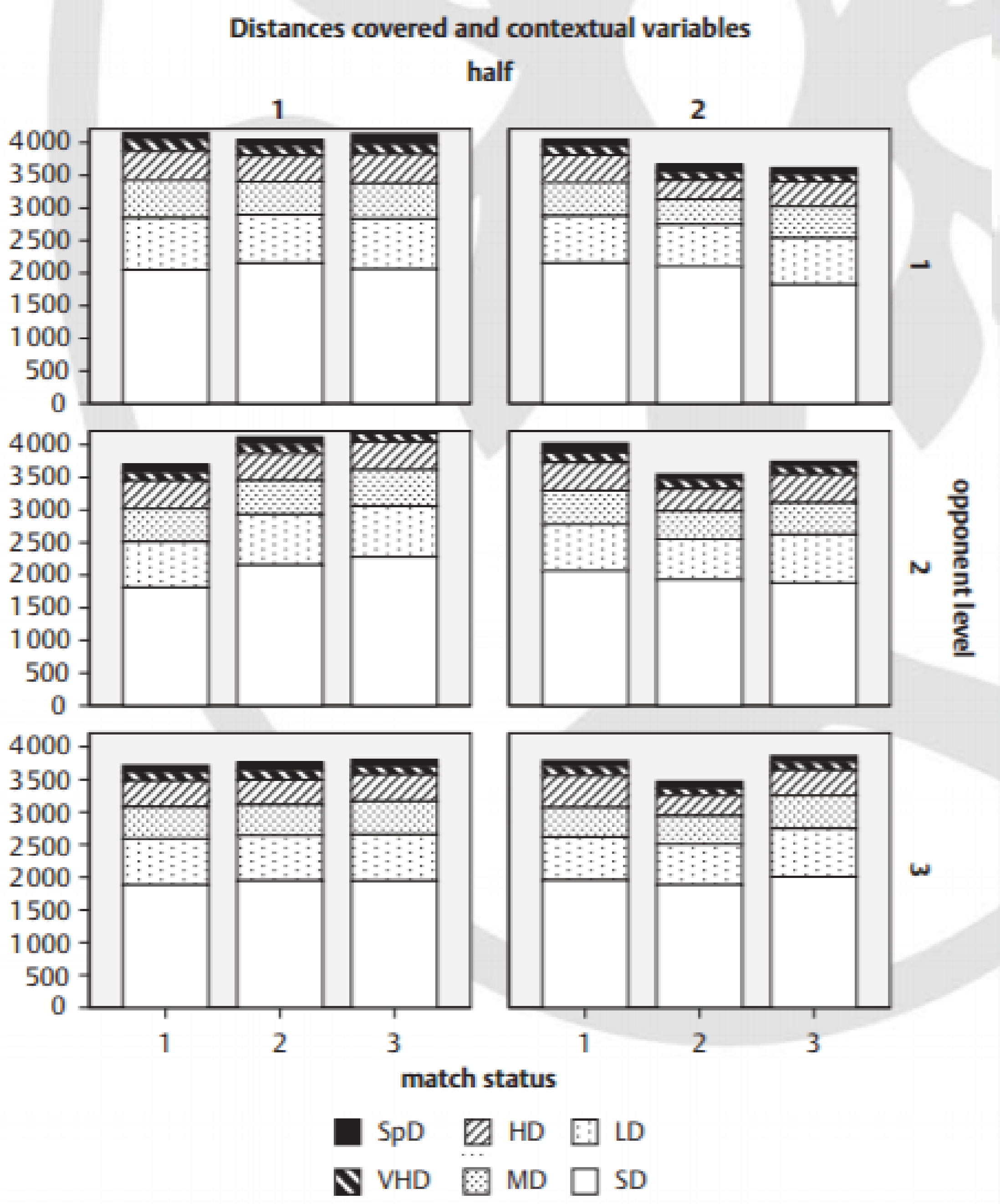

Fig. 1 Distances covered and contextual variables. Running intensities are: SD (0–11 $Km \cdot h^{-1}$); LD (11.1–14 $Km \cdot h^{-1}$); MD (14.1–17 $Km \cdot h^{-1}$); HD (17.1–21 $Km \cdot h^{-1}$); VHD (21.1–24 $Km \cdot h^{-1}$); and SpD (>24 $Km \cdot h^{-1}$). *Opponent level* was Top (1), Medium (2) and Bottom (3). *Halves* were First (1) and Second (2). *Match status* was Lose (1), Draw (2) and Win (3).

With respect to the opponent level, the poorer the quality of the opponent, the shorter the distance covered by the reference team.

Int J Sports Med. 2007 Dec;28(12):1018-24. Epub 2007 May 11.

Variation in top level soccer match performance.

Rampinini E[1], Coutts AJ, Castagna C, Sassi R, Impellizzeri FM.

Author information

Abstract

This study examined the influence of the opposing team, seasonal variations and the influence of first half activity on match performance in top-level soccer players. Physical performance measures were collected using the ProZone match analysis system from 20 professional soccer players from the same team and their opponents (n = 188) during a season. Match activities (standing, walking, jogging, running, high-speed running and sprinting), distances (total distance [TD], high-intensity running [HIR] and very high-intensity running [VHIR]) and other measures including involvement with the ball and peak running speed were collected. The influence of opponent team, the level of opposition, first half physical activities on second half activities, and playing position were analysed. The main finding was that TD ($r = 0.62$, $p < 0.05$), HIR ($r = 0.51$, $p < 0.05$), and VHIR ($r = 0.65$, $p < 0.05$) of the reference team was influenced by the activity profile of the opponent teams. The TD and HIR was higher against Best opponent teams compared to Worst opponent teams ($p < 0.05$), and the TD, HIR and VHIR travelled in the first half significantly influenced the distances covered in the second half. TD, HIR and VHIR were greater at the end of the season. These results may be used to interpret meaningful changes in match performance in top level soccer.

MATCH LOCATION

Several studies of the relationship between match location and work rate in soccer showed that home teams cover greater distances than away teams during low-intensity activity (Lago et al., 2010; Lago-Peñas et al., 2009; Zubillaga et al., 2007). Other studies suggest that the effect of this factor should be addressed in the interaction with other situational variables (e.g. playing at home and losing against a weak opponent) (Castellano et al., 2011).

INTERACTIVE EFFECTS

Existing notational analysis has provided preliminary information on the effects of situational variables such us match location, match status, and quality of the opponent on sports performance at a behavioural level. Most of previous research has examined situational variables independently not accounting for the possibility of higher-order interactions (e.g. playing at home and losing). However, the examination of situational variables in isolation would appear to provide limited insight into the complex nature of team sports performance (McGarry and Franks, 2003; Reed and O´Donoghue, 2005).

…what I‘am working on right now…

Sports Med
DOI 10.1007/s40279-016-0562-5

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LEADING ARTICLE

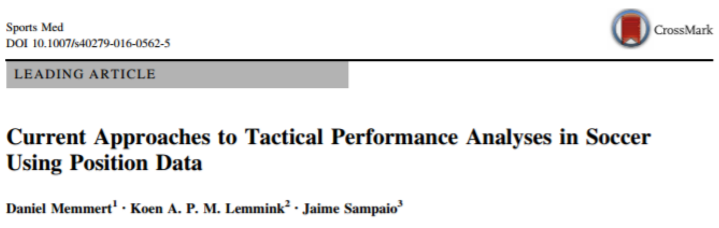
Current Approaches to Tactical Performance Analyses in Soccer Using Position Data

Daniel Memmert[1] · Koen A. P. M. Lemmink[2] · Jaime Sampaio[3]

Table 1 Candidate performance indicators for tactical performance analysis based on position data

Key performance index	Method	Description	References
Length, width, space	Distance	Measures the average expansion of a team in the direction of x and y or rather in both dimensions	Castellano et al. [19], Moura et al. [20]
Space control	Voronoi	Models space control with the help of a Voronoi diagram	Fujimura and Sugihara [21], Fonseca et al. [22], Taki and Hasegawa [23], Kang et al. [24], Horton et al. [25]
Event recognition	Rule-based, decision trees	Recognizes events from position data such as passes, goals, offside; rule-based system	Gudmundsson and Wolle [26], Wei et al. [27],
Route clustering	Clustering algorithms (Fréchet distance)	Filters subgroups from movement patterns of one or more players	Gudmundsson and Wolle [26], Hirano and Tsumoto [28]
Pass evaluation	Motion model and passable area	Calculates regions, such as the 'passable area', for every pass based on a motion model and evaluates passes according to difficulty or decision quality	Horton et al. [25], Gudmundsson and Wolle [29]
Distance from the team's centre	Euclidian metrics	Calculates the players' average, minimal and maximal distance from the team's centre	Sampaio and Maçãs [30], Bialkowski et al. [31]
Formation	Mean average, main component analysis	Calculates the average position and thus determines an actual tactical formation	Bialkowski et al. [32]

Fig. 1 Team formation and predictability of distances between players and their positional-centroid. The results show the players' predictability in relation to their positional-centroid, as measured by the approximate entropy from the distance between each player and their positional-centroid. A cluster analysis automatically classified the predictabilities in three different groups (higher, medium and lower). The performance of the highly predictable players is also described with the average ± standard deviation of the distance to positional-centroid. *GK* goalkeeper, *CD* central defender, *LD* left defender, *RD* right defender, *CM* central midfielder, *LM* left midfielder, *RM* right midfielder, *FW* forward, *CF* central forward, *RF* right forward, *LF* left forward, *Cdef* defensive centroid, *Cmid* midfield centroid, *Cfw* forward centroid



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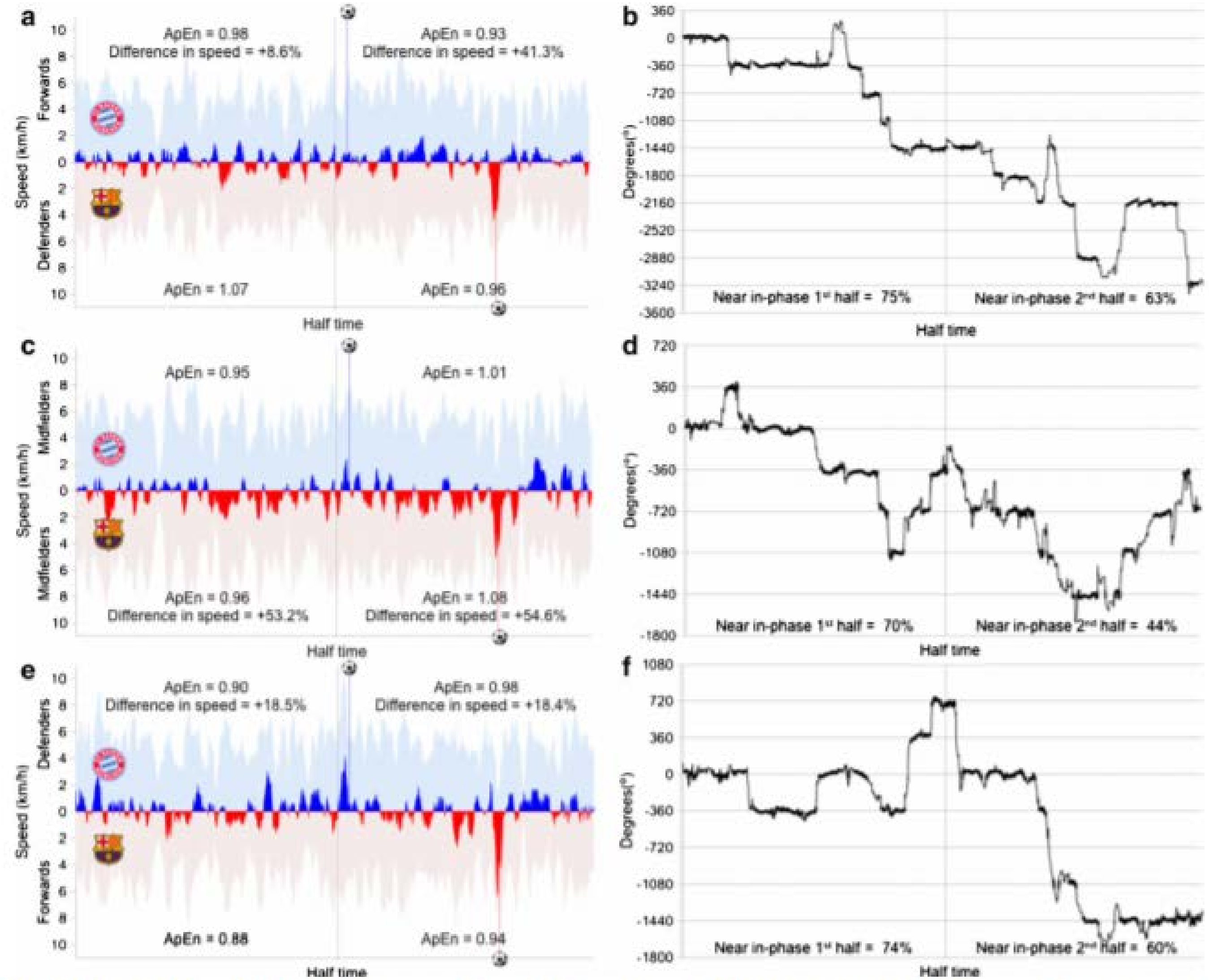

Fig. 2 Depiction of confrontations between **a**, **b** defenders versus opponents' forwards; **c**, **d** midfielders versus midfielders; and **e**, **f** forwards versus opponents' defenders. **a**, **c** and **e** show in lighter shading the average speed of the players of each team and, in darker shading, the difference between both teams. The approximate entropy (ApEN) shows the predictability from the speed time series and the percentage (%) shows the amount of time that players in one team were faster or slower than their opponents in each half of the match. **b**, **d** and **f** show how the speeds were synchronised during the match (relative phase results) and the percentage of near-in-phase represents the amount of time that players were synchronised in each half of the match. The values close to 0° and 360° multiples refer to simultaneous patterns of synchronisation (i.e. in-phase, in which speeds are synchronised and both are increasing or both are decreasing), whereas values close to 180° and 360° multiples refers to asynchronous patterns of synchronisation (i.e. anti-phase, in which speeds are synchronised and present different trends, one increasing and the other one decreasing or vice-versa)

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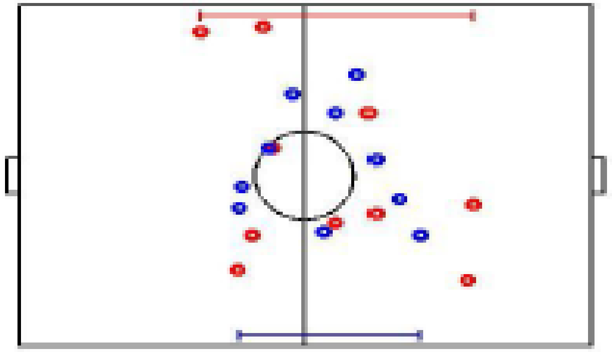
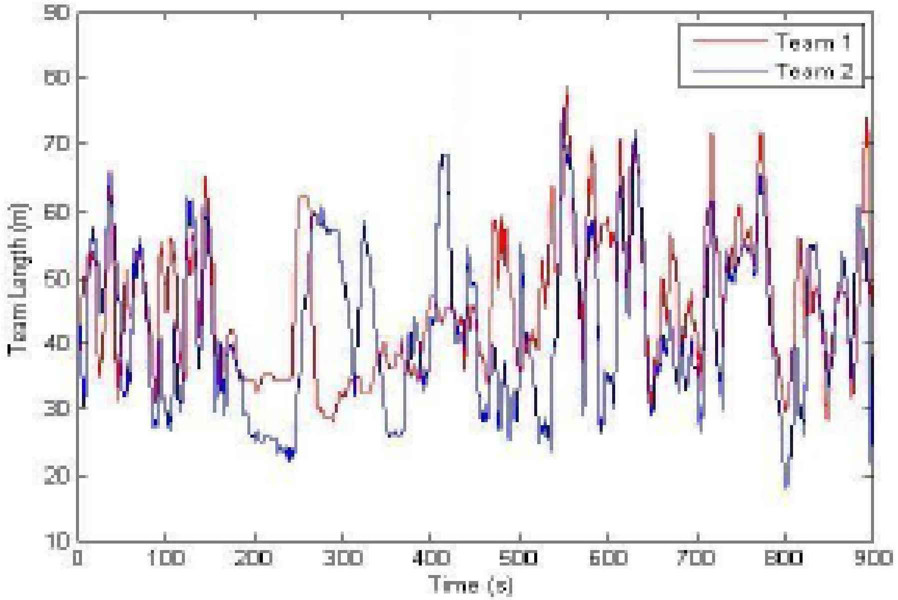
Team length

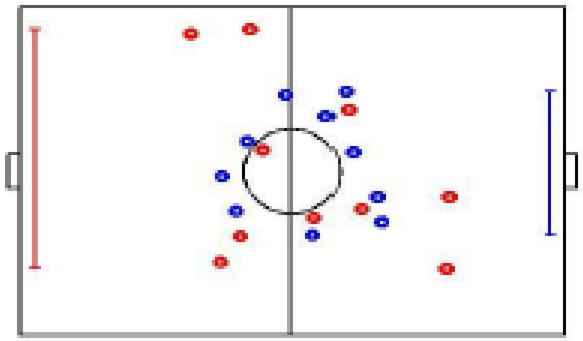


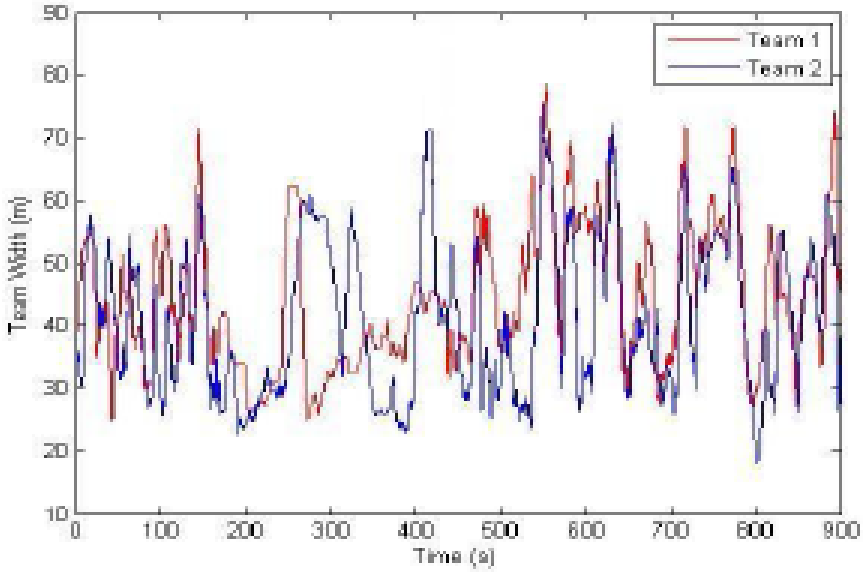


Computation details: calculated as the difference between the maximum and minimum positions of players in the field's longitudinal dimension in each time frame.

Meaning: This variable captures the compactness of the whole team and its variation as a function of changes in performance constraints. It can be used in the monitoring of specific reference values for team length, or to evaluate depth differences between teams.

Team width

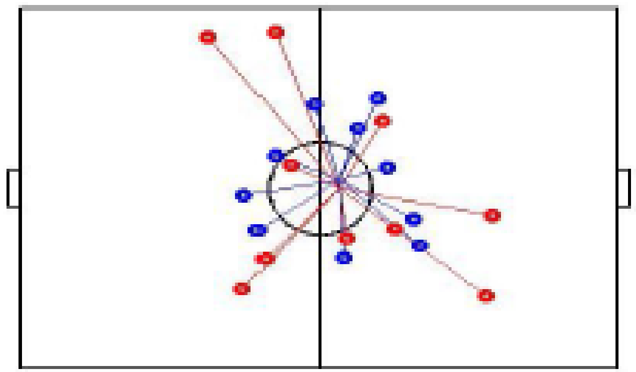


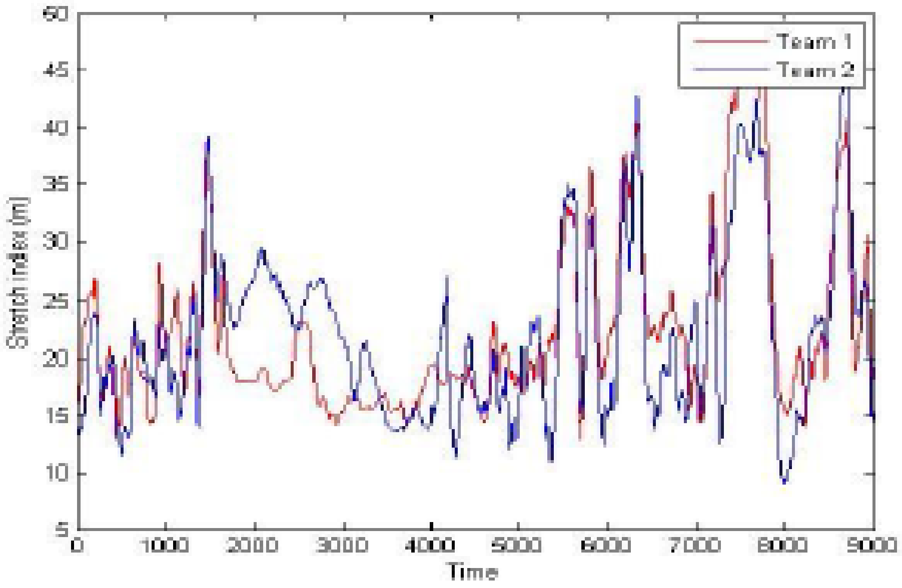


Computation details: calculated as the difference between the maximum and minimum positions of players in the field's lateral dimension in each time frame.

Meaning: When in defence, the width of a team may reveal the potential for the opponents to find inner or outer spaces to penetrate. When attacking, it may indicate the lateral spread of the team.

Stretch index

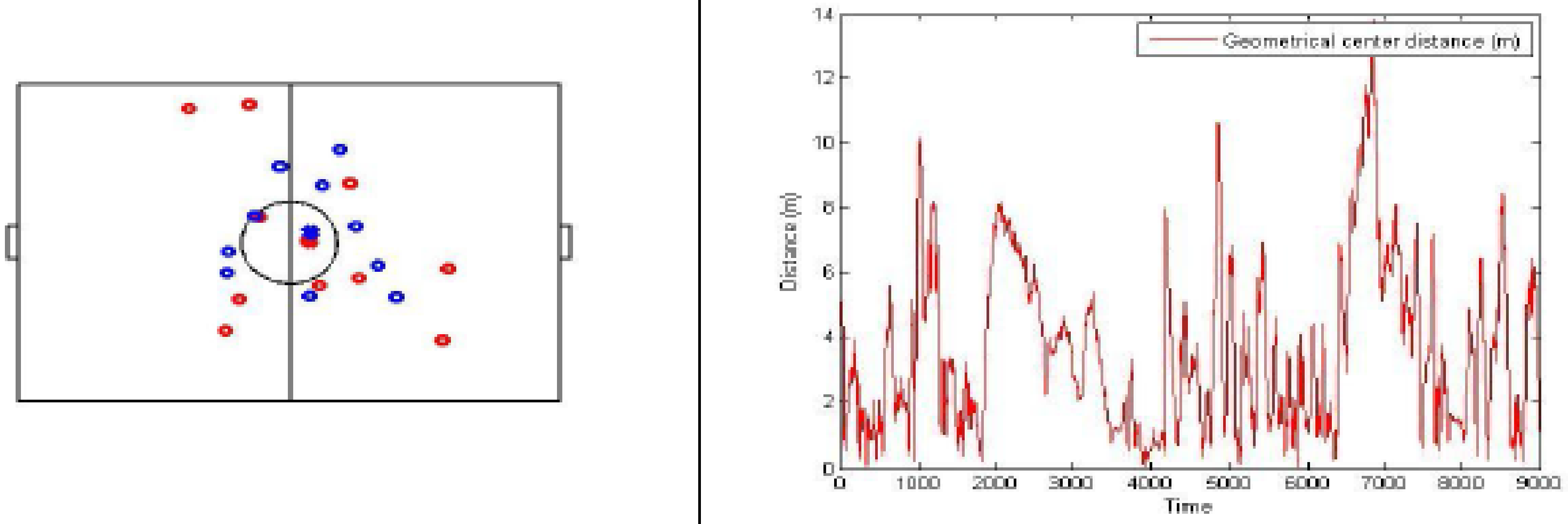




Computation details: computed as the average of the vectorial distance of each player to the corresponding team's centre [8] (it can be alternatively calculated decomposing positions in x- and y-axis of motion [9]).

Meaning: This compound variable captures the synergistic counter-phase relation of contraction and expansion behaviours of teams as a function of exchanges in ball possession [9]. First derivative of this measure may also evidence the speed at which teams stretch or shorten their dispersion on the field.

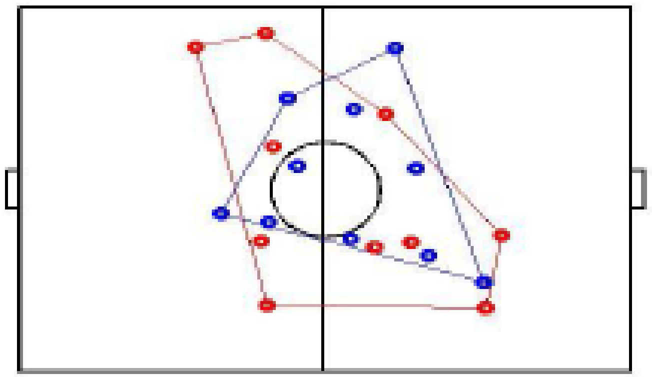
Team centre

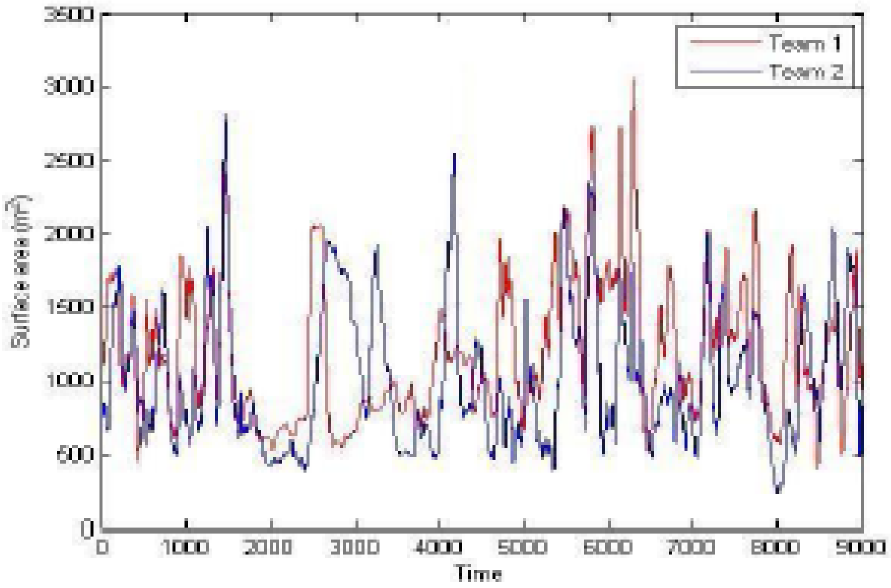


Computation details: calculated as the mean position of all team players over time in each axis of motion. Distance between team centres can also be measured (right panel).

Meaning: Based on the mean point or "centre of mass" of a team, this variable captures its global oscillatory movements such as movements towards or away from the goals or the sidelines. Distance between the team centres can also be used as an indicator of the closeness of teams.

Surface area

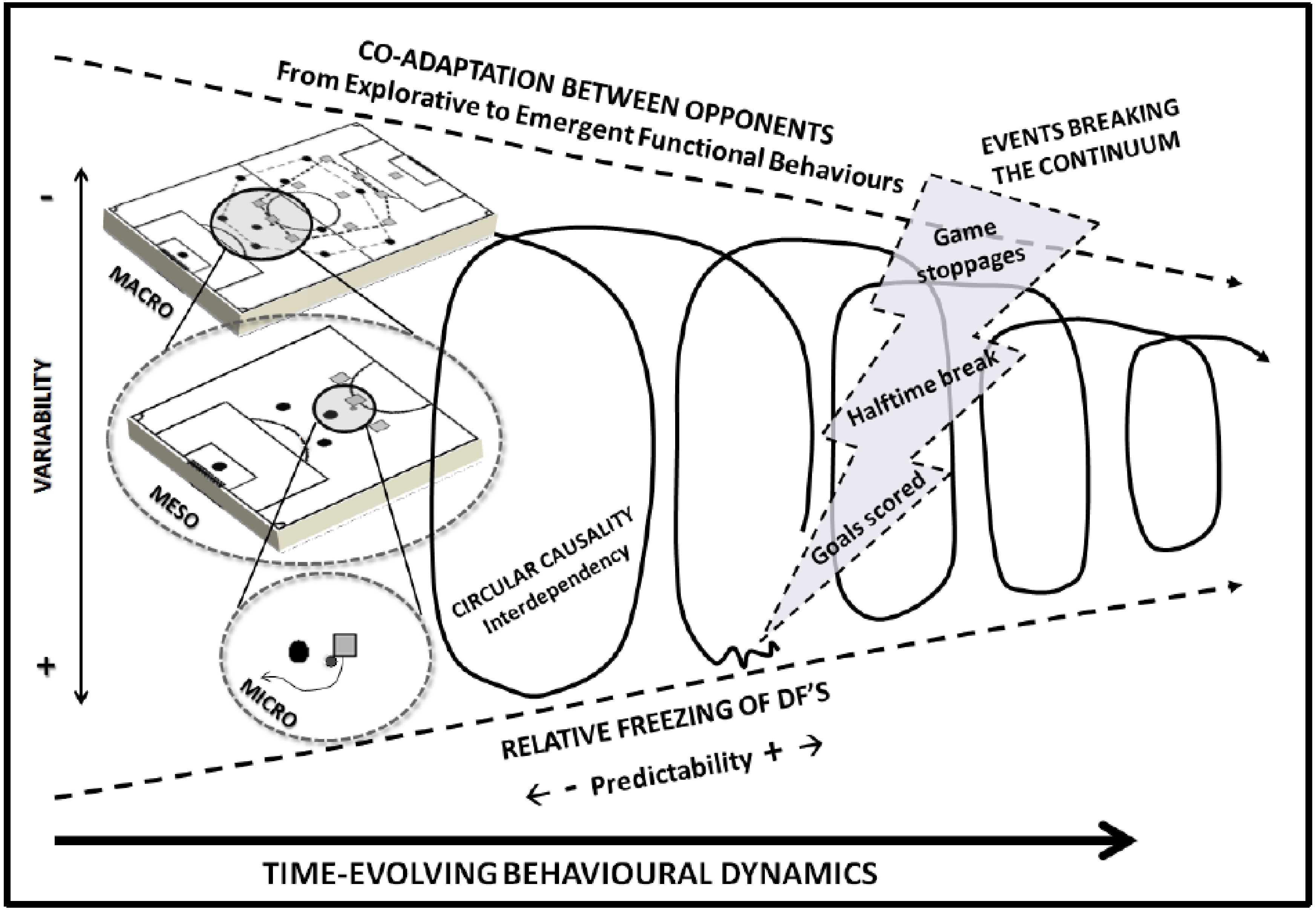




Computation details: calculated as the area of a polygon drawn by linking the externally positioned players in each team's formation. These values were computed using Matlab functions (convhull) employing the rule of a convex polygonal area (see left panel).

Meaning: This compound variable expresses the relation between the shapes and the occupied spaces of the two teams, and how they change over time. Overlapped areas can also be obtained.

A conceptual model of association football performance



(Duarte (2012)

A conceptual model of association football performance

The conceptual model captures the interdependence between the different levels of organization ranging from dyads to collectives (i.e., 1vs1, 3vs3 and 11vs11). This interdependence implies a circular causality which means that each individual performer reciprocally influences and are influenced by team's behavior. However, this cyclical and channelling flow is broken by some game events such as goals scored and halftime, and also stoppages in play for substitutions and injuries assistances.

(Duarte (2012)

Proc. Natl. Acad. Sci. USA
Vol. 88, pp. 2297–2301, March 1991
Mathematics

Approximate entropy as a measure of system complexity

(statistic/stochastic processes/chaos/dimension)

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Communicated by Lawrence Shepp, December 7, 1990 (received for review June 19, 1990)

ABSTRACT **Techniques to determine changing system complexity from data are evaluated. Convergence of a frequently used correlation dimension algorithm to a finite value does not necessarily imply an underlying deterministic model or chaos. Analysis of a recently developed family of formulas and statistics, approximate entropy (ApEn), suggests that ApEn can classify complex systems, given at least 1000 data values in diverse settings that include both deterministic chaotic and stochastic processes. The capability to discern changing complexity from such a relatively small amount of data holds promise for applications of ApEn in a variety of contexts.**

In an effort to understand complex phenomena, investigators throughout science are considering chaos as a possible underlying model. Formulas have been developed to characterize chaotic behavior, in particular to encapsulate properties of strange attractors that represent long-term system dynamics. Recently it has become apparent that in many settings nonmathematicians are applying new "formulas" and algorithms to experimental time-series data prior to careful statistical examination. One sees numerous papers concluding the existence of deterministic chaos from data analysis

If one cannot hope to establish chaos, presumably one is trying to distinguish complex systems via parameter estimation. The parameters typically associated with chaos are measures of dimension, rate of information generated (entropy), and the Lyapunov spectrum. The classification of dynamical systems via entropy and the Lyapunov spectra stems from work of Kolmogorov (3), Sinai (4), and Oseledets (5), though these works rely on ergodic theorems, and the results are applicable to probabilistic settings. Dimension formulas are motivated by a construction in the entropy calculation and generally resemble Hausdorff dimension calculations. The theoretical work above was not intended as a means to effectively discriminate dynamical systems given finite, noisy data, or to certify a deterministic setting. For all these formulas and algorithms, the amount of data typically required to achieve convergence is impractically large. Wolf *et al.* (6) indicate between 10^d and 30^d points are needed to fill out a d-dimensional strange attractor, in the chaotic setting. Also, for many stochastic processes, sensible models for some physical systems, "complexity" appears to be changing with a control parameter, yet the aforementioned measures remain unchanged, often with value either 0 or ∞.

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Application of entropy measures to analysis of performance in team sports

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Abstract

Over the last years, several researchers have been claiming that team ball sports may be viewed as dynamical systems and, thus, they should be thoroughly investigated using congruent concepts and tools. The study of variability in the sport performance domain has shown potential to contribute with valuable information about tactical behaviours related with space and time management within ever changing task constraints featuring team sports contests. Here we detail how different entropy measures have been applied to the study of performance variability to uncover the interactions underlying players and teams' performances. With that purpose, urging issues related with information entropy, approximate entropy and sample entropy applications are discussed as a mean to enrich the state of the art in team sport performance. In sum, measurements of entropy in team sports have shown great potential to assess the uncertainty of players' spatial distributions and dominant regions areas and of several collective team behaviours (e.g., team synchrony and team dispersion) throughout the course of a match. Entropy can also be used as a potential tool to identify expert performances and differentiate skilled from novice athletes. Future holds many other applications of this statistic in the context of performance analysis in sports, and the inclusion of new and more sophisticated entropy algorithms.

Keywords: variability, sports teams as complex systems, Shannon entropy, approximate entropy, sample entropy.


IJSM/2249/19.1.2012/Macmillan Behavioural Sciences 1

Measuring Football Tactical Behaviour

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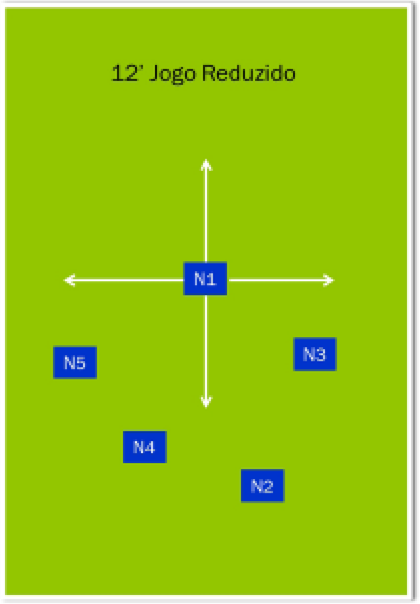
[2] Research Center for Sports Sciences, Health and Human Development, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

GPS - Posição dos jogadores (5 registos em cada segundo)

Março (pré-teste)

60 mts (y)

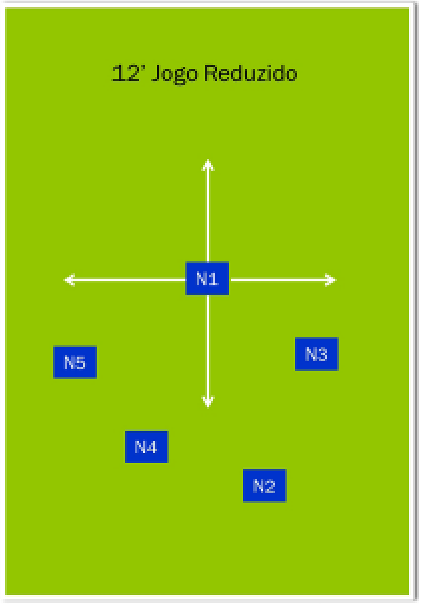


40 mts (x)

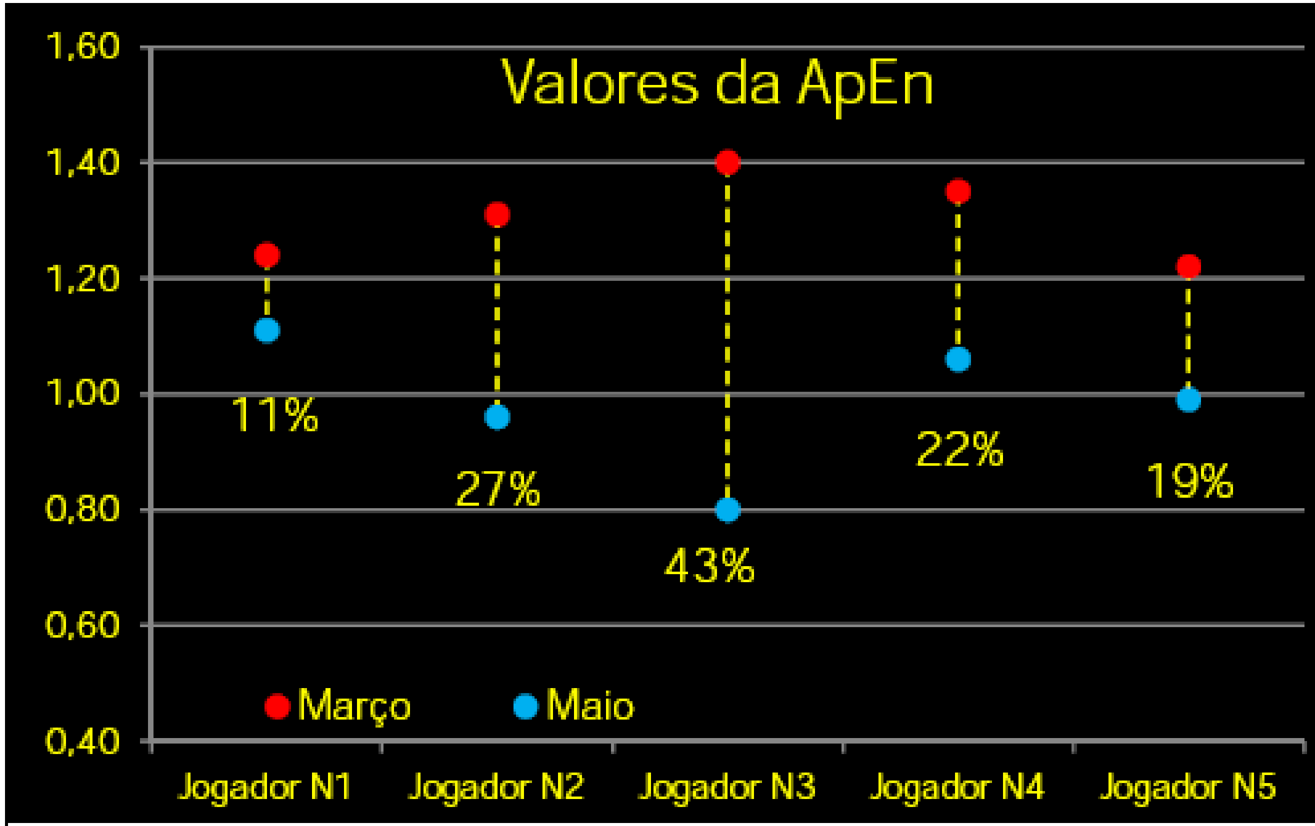
Ensino do Jogo de Futebol (26h teórico práticas)

Maio (pós-teste)

60 mts (y)



40 mts (x)



Médias
Março 1,30±0,07
Maio 0,98±0,11
Δ 0,32±0,16
% 25±11


IJSM/2249/19.1.2012/Macmillan Behavioural Sciences 1

Measuring Football Tactical Behaviour

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[2] Research Center for Sports Sciences, Health and Human Development, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal

Houve diminuição da imprevisibilidade no padrão de todos os jogadores... a dinâmica posicional é em Maio menos aleatória do que em Março...

Ensino do Jogo de Futebol (26h teórico práticas)

→ Melhor performance táctica?

TAKE-HOME MESSAGES

Thanks for listening, any questions?