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Small-sided games in high-level football: integrating physiological, perceptual and tactical performances

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Orientador: Professor Doutor António Jaime da Eira Sampaio

Universidade de Trás-os-Montes e Alto Douro
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Este trabalho foi expressamente elaborado com vista à obtenção do grau de Doutor em Ciências do Desporto de acordo com o Decreto-lei 115/2013 de 7 de agosto.

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"Daria tudo o que sei pela metade do que ignoro"

René Descartes

Ao meu sol Ary

Para sempre!

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RESUMO

Os jogos reduzidos (SSG) ganharam uma grande importância no treino de futebol. O objetivo geral deste trabalho foi estudar a influência do número de jogadores na resposta fisiológica, perceção do esforço, perfil de atividade e coordenação interpessoal dos futebolistas. A população do estudo foi constituída por 10 futebolistas de elite do escalão sub 19. Os atletas participaram em quatro formatos de SSG (2x2; 3x3; 4x4 e 5x5), com a duração de 20 minutos (3x6 minutos com 1 minuto de recuperação ativa) e a área relativa por jogador foi sempre de 150m^2. Avaliaram-se as respostas fisiológicas e os perfis de atividade nos diferentes formatos de SSG. Os valores mais elevados de frequência cardíaca e deperceção subjetiva do esforço foram encontrados nos formatos 2x2 e 3x3. O formato 2x2 apresentou a menor distância total percorrida e o menor número de sprints, já o 3x3 apresentou o maior número de sprints. Relativamente à carga corporal, foram encontradas diferenças estatísticas entre os SSG, sendo que, o formato 4x4 apresentou o maior valor e o 5x5 o menor. A carga corporal diminuiu a cada 2 minutos. Este trabalho sugere que os treinadores podem usar formatos mais reduzidos (2x2 e 3x3) para aumentar as exigências cardiovasculares durante o treino. Por outro lado, quando se pretende aumentar a variabilidade e a especificidade de acordo com as exigências da competição, devem ser usados formatos com maior número de atletas (4x4 e 5x5). O comportamento tático dos atletas durante os SSG foi avaliado recorrendo a variáveis posicionais e existiu o reconhecimento de padrões de coordenação interpessoal entre os atletas ao longo dos SSG. Foi identificada uma relação direta entre o número de jogadores e a distância ao centróide da equipa e da equipa adversária, sendo que o oposto aconteceu com os valores de entropia aproximada. Existiu menor aleatoriedade nos SSG com maior número de jogadores sugerindo uma melhor organização posicional. Foi detetada uma relação entre os ângulos realizados pelos pares de jogadores e o centróide da própria equipa, sugerindo a existência de diferentes relações entre os jogadores. Os SSG com maior número de jogadores foram os mais indicados para consolidar os comportamentos de auto-organização. As tendências de coordenação interpessoais intra- e inter-equipa permitiram discriminar a duração das sequências de posse de bola. As sequências mais curtas exibiram maior irregularidade do que as mais longas.

Palavras chave: futebol, jogos reduzidos, treino, perfis de atividade, carga corporal, sistemas complexos, sistemas dinâmicos, entropia aproximada, coordenação interpessoal, GPS, variáveis posicionais, posse de bola.

ABSTRACT

Small sided-games (SSG) have gained a major importance in football training. The main goal of this work was to study the influence of the players' number in the physiological response, rating of perceived exertion (RPE), activity profile and footballers interpersonal coordination. The population study was composed by 10 elite U19 football players. The players participated in four SSG formats (2x2; 3x3; 4x4; 5x5), with 20 minutes duration (3x6 minutes with 1 minute of active recovery) and the ratio area:player was kept constant at 150m^2. The physiologic responses and activity profiles in different SSG formats were assessed. The highest values of heart rate and RPE were found in 2x2 and 3x3 formats. The 2x2 format presented the smallest total distance and sprints number, whereas the 3x3 format showed the highest number of sprints. Regarding to the body load, statistical differences were found among the SSG. The 4x4 format presented the highest value and the 5x5 the smallest. The body load decreased in each 2 minutes. This work suggests that coaches can use more reduced formats (2x2 and 3x3) to increase the cardiovascular demands during conditioning. On the other hand, when it intends to increase variability and specificity in accordance with competition demands, it should be used formats with higher athletes' number (4x4 and 5x5). The tactical behaviour of athletes during SSG was evaluated through positional variables and there was the recognition of interpersonal coordination patterns among athletes during the SSG. A relationship between the players' number and the centroid distance of team and the opponent team was established, and the contrary happened with the approximate entropy values. There is a smallest random in SSG with highest players' number suggesting a better positional organization. A relationship between players positioning angles' and team centroid, suggested the existence of different communication pathways among players. The SSG with highest number of players are the most advised to consolidate the self-organizing behaviours. The intra- and inter-team interpersonal coordination tendencies allow to discriminate the duration of ball possession sequences. The shortest sequences exhibited a highest irregularity than the longest ones.

Key-words: football, small-sided games, conditioning, activity profiles, body load, complex systems, dynamical systems, approximate entropy, interpersonal coordination, GPS, positional variables, ball possession.

LIST OF PUBLICATIONS AND COMMUNICATIONS

During the developmental stages of this thesis, some work has been published, accepted or submitted for publication in peer-reviewed journals, as well as, presented at scientific meetings originating some publications in proceedings and abstract books. Forthcoming we present a selection of the publications and communications specifically related with the work developed in this thesis.

PEER-REVIEWED PAPERS IN INTERNATIONAL JOURNALS (ISI)

Aguiar, M., Gonçalves, B., Botelho, G., Duarte, R. and Sampaio, J. (submitted). Regularity of interpersonal coordination discriminates short and long sequences of play in small-sided football games.

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Aguiar, M., Botelho, G., Gonçalves, B. and Sampaio, J., 2013. Physiological responses and activity profiles of football small-sided games. *Journal of Strength and Conditioning Research*, 27(5), 1287-1294. doi: 10.1519/JSC.0b013e318267a35c. IF = 1.8

Aguiar, M., Botelho, G., Lago, C., Maçãs, V. and Sampaio, J. (2012). A review on the effects of soccer small-sided games. *Journal of Human Kinetics*, Section III – Sports Training, 33: 103-113. DOI: 10.2478/v10078-012-0049-x. IF = 0.4

COMMUNICATIONS AT SCIENTIFIC MEETINGS

Oral Communications

Marco Aguiar, Goreti Botelho, Bruno Gonçalves and Jaime Sampaio, 2013. Activity profiles of four different football small-sided games. Mini-oral presentation. Abstract ID: 134, PP-PM67 Training and Testing [TT] 2. Unifying Sport Science. 18th Annual Congress of the ECSS (European College of Sport Science). Barcelona, Spain.

M**arco Aguiar**, Goreti Botelho, Bruno Gonçalves and Jaime Sampaio, 2012. Tactical behaviour in four different small-sided football games. World Congress of Performance Analysis of Sport IX. Podium presentation POD 13.4, Session 13, Soccer 3. 25-28 July, University of Worcester, England.

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Marco Aguiar, 2012. Complexidade e jogos reduzidos no futebol. Comunicação oral apresentada no Seminário "CIDESD - Júnior" organizado pelo Centro de Investigação em Desporto, Saúde e Desenvolvimento Humano (CIDESD), realizado na Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal.

Marco Aguiar, 2011. Constrangimentos nas respostas à prática de jogos reduzidos. Comunicação oral apresentada no Seminário "Fundamentos e aplicações da investigação aos jogos desportivos coletivos" organizado pelo Centro de Investigação em Desporto, Saúde e Desenvolvimento Humano (CIDESD), realizado na Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal.

LIST OF ABBREVIATIONS

a.u. – arbitrary units

Acc – accumulated

ANOVA - analysis of variance

ApEn – approximate entropy

CNT - player-to-own centroid distance

e.g. – "exempli gratia"

et al. – "*et alii*"

Etc – "*et cetera*"

GPS - global Positioning System

HR – heart rate

HR_{max} - maximum heart rate

i.e. – "*id est*"

$km.h^{-1}$ - kilometers per hour

m – meters

m^2 - square meter

min - minutes

n – number

OPCNT - player-to-opponent centroid distance

PC – personal computer

PI = predictor importance

RPE - rating of perceived exertion

SD – standard deviation

Sec - seconds

SPSS – statistical Package for the Social Sciences

SSG - small-sided games

U19 – under 19

vs. – "*versus*"

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CHAPTER 1

1. GENERAL INTRODUCTION

1.1. INTRODUCTION

Football is probably the most popular sport in the world, with more than 400 million active player's worldwide. Despite its universal nature and its formal history extended back over an hundred years, there are still many uncertainties concerning its multidimensional requirements (physiological, psychological, biomechanical) and, therefore, uncertainties when planning for optimal training and conditioning. In fact, this game is very complex because the pitch is substantially large (approximately 100 x 60 m), the ball is controlled with the feet and head and there may be interactions within eleven teammates and between eleven opponents, almost all with different roles in the game[1].

Science and football are not terms that would intuitively be linked together by football fans. Success in football is frequently explained by the "artistry" of both managers and players. As a consequence, terms such as intuition, imagination, quick decision-making and personality are more likely to be associated with victories than any principles and processes associated with scientific research[2]. Despite the difficulty to accurately define the origins of science and football relationship, the first football related papers date back to the 1960's and 1970's and had a great increase in the recent years. Since these early efforts the available scientific knowledge related to football has been developed substantially.

The capability of this scientific information to influence practice in the day-to-day activity of football organisations, especially elite teams, has been largely taken for granted. However, a close examination of this impact can lead to more uncertainty regarding the usefulness of the scientific data to the sport[2]. Therefore, the bridge between theory and practice should be enhanced in order to improve players and team performance. This could be reached by the recent change in the frameworks used to generate new knowledge.

Team sports performance can be described as the result of a long term training process[3]. Over the years, sports science tried to understand the game in order to develop training programs that provide team sports coaches with reliable methods to improving training while enhancing players' performance[4]. Based on the positivist paradigm, that have the reductionism as core concept (which is an attempt to understand the functioning of the whole through an analysis of its individual parts[5]), firstly sports science focused on their attention in the training of specific physiological fitness indices, perceptual skills, and technical or tactical actions through use of repetitive practice drills often performed in isolation from the competitive performance context[6]. Despite the reported benefits, this research line has been criticized because it neglects the active role of the performance environment in shaping movement behavior and decision making[7], sustaining a dysfunctional rupture in the performer-environment relationship (cf. the concept of organismic asymmetry in sports science[8]). These methods are somewhat reductionist, failing to enhance understanding of the functional utility of specific actions in sub phases of team games[9].

Instead of this approach, a new research direction focused on the player-environment relationship was followed recently. This lead to the development of a new and more "integrated" knowledge production that allows a better comprehension about the complex practical and environmental challenges associated to the game. The unpredictable, noisy, dynamic performance environments found in competitive team games in which information sources rarely assured in advance and emergent actions are highly context dependent[9, 10] began to be taken into account. This research line arises from the need of to incorporate the variability and uncertain in the interpersonal interactions between players and teams resulting from active opposition. Therefore, science and training task in team sports needs to assimilate specifying variables (i.e., key informational sources) from competitive performance environment that individuals use to regulate actions and make decisions.

The ecological dynamics theoretical approach can be a useful and powerful tool to achieve these variables assimilation. This method allows to describe how individual players and sports teams can be modulated as complex systems, which are essentially nondeterministic. Such social neurobiological systems exhibit patterns of coordination at a global system level, i.e., movement patterns in individuals and interpersonal interactions at a team level in the sport performance context[4]. These coordination tendencies continuously emerge from constant interactions between system components (within and between individual players)[4, 11].

This new approach is more holistic based on collective variables, such as, covered area, geometric shape designed by team members or the common team centre[12]. Therefore, to better understand team sports performance, collective positional variables should be studied based on the player´s relative positioning in the pitch.

1.2. AN OVERVIEW ABOUT SMALL-SIDED GAMES

In team sports conditioning, repetitive practice of isolated and discrete movement patterns is a reductionist approach that only prepares for producing consistent movement patterns in predictable performance environments. Instead, program on team games preparation needs to represent the unstable, dynamic, and unpredictable nature of team games. This can be reached with the recreation of game simulations by manipulating practice areas, objectives and rules. In this context, the popularity of small-sided games (SSG) increased in the recent years.

The SSG are modified games that are played on reduced pitch areas, using adapted rules and involving a smaller number of players[13]. Currently, SSG study is one of the most addressed topics in football contemporary research[14, 15]. The increase of curiosity about this area is coincident with the increase of popularity obtained by specific football conditioning, which involves training players to deal with football situations on the basis of what is required in a given match situation. In fact, SSG allows to preserve the complexity and the basic variability properties of the game and, to reduce the interactions and to increase the ratio of players' participation in decision making[14-20]. SSG in football are widely considered to offer many practical advantages that have lead to its popularity as a training modality at all ages and levels[13]. The primary benefits of SSG are that they appear to replicate the movement demands, physiological intensity and technical requirements of competitive match[21-23], whilst also requiring players to make decisions under pressure and fatigue[24]. SSG have also been suggested to facilitate the development of technical skills and tactical awareness within the appropriate context of the game[23]. Compared with traditional fitness game sessions, SSG are thought to increase player compliance and motivation, since it is perceived to be sport specific[22, 23]. Finally, SSG are considered to be more efficient since the physical performance, technical and tactical awareness can be developed simultaneously[22, 23]. However, the realization of these advantages is depending on SSG design[14]. In fact, it has been reported that physiological responses (e.g. heart rate, blood lactate concentration and rating of perceived exertion), perceptual, and physical loads can be modified during SSGs by altering factors, such as, the number of players, the size of the pitch, the rules of the game, the availability of replacement balls, the training regimen, the presence of goalkeepers and coach encouragement[1, 6, 13-15, 19, 24-36]. Furthermore, the systematic exposure to SSG during training sessions have been suggested to improve players' decision making, technical skills, tactical awareness through functional movements[37]. However, there is a lack of knowledge regarding the tactical requirements elicited by SSG, and their corresponding transfer to match performance[13]. In this context, the present thesis should be regarded as an input to add knowledge in this so promising area.

1.3. AIM OF THE THESIS

Despite its popularity as specific football conditioning, there is relatively scarce information regarding how SSG can be used to improve physical capacities and technical or tactical skills. By this, the first aim of this thesis is to contribute to a better understanding of how SSG could be characterized as conditioning drills.

This work emphasizes the SSG characteristics as conditioning drills highlighting the physiological, perceptual, and dynamical characteristics complemented with the informational constrains of competitive performance, particularly the interpersonal coordination processes between players' movements.

Together, all studies contribute to a better understanding of player's physiological, perceptual and dynamical response to different SSG formats.

1.4. STRUCTURE OF THE THESIS

A collection of four original research articles, submitted or published on peer-reviewed international journals with ISI Impact Factor constitute the main body of this thesis. Each article is presented as an individual chapter following the format requested by the scientific journal for where it was submitted.

The current chapter (Chapter 1) introduce the general conceptual and scientific fundamental supporting the SSG in football. Additionally, the general aim of the thesis is also presented.

Chapter 2 presents "**A review on the effects of soccer small-sided games**" in which an overview of the literature published in the last decades is discussed.

In Chapter 3, an experimental research article entitled "**Physiological responses and activity profiles of football small-sided games**" is presented. This work researched the acute physiological responses and activity profiles of four football SSG formats (2-, 3-, 4- and 5-a-side).

Chapter 4 introduces another experimental research article entitled "**Tactical behaviour during four small-sided games in football**". This study was focused on the description of tactical behaviour in SSG in football using positional data (x and y coordinates).

Chapter 5 addresses the study "**Regularity of interpersonal coordination discriminates short and long sequences of play in small-sided football games**". The aim of this study was to find if the structure underlying the interpersonal coordination tendencies discriminate the length of possession sequences, using cluster analysis.

Finally, Chapter 6 provides an overview of the main results of all the studies showed in this thesis. Based on the major findings, some important considerations for future research are also presented.

1.5. REFERENCES

1. Aguiar M, Botelho G, Lago C et al. A Review on the Effects of Soccer Small-Sided Games. *J Hum Kinet* 2012; 33:103-113.
2. Drust B, Green M. Science and football: evaluating the influence of science on performance. *J Sport Sci* 2013; 31(13):1377-1382.
3. Sampaio J, Maçãs V. Measuring tactical behaviour in football. *Int. J. Sports Med.* 2012; 33(5):395-401.
4. Davids K, Araújo D, Correia V et al. How Small-Sided and Conditioned Games Enhance Acquisition of Movement and Decision-Making Skills. *Exerc Sport Sci Rev* 2013; 41(3):154-161.
5. Brustad RJ, *A critical post-modern perspective on knowledge development in human movement*, in *Critical postmodernism in human movement, physical education and sport*, J.M. Fernandez-Balboa, Editor 1997, University of New York.: Albany. p. 87-98.
6. Tessitore A, Meeusen R, Piacentini MF et al. Physiological and technical aspects of "6-a-side" soccer drills. *J Sports Med e Phys Fit* 2006; 46(1):36-43.
7. Davids K, Araújo D, Hristovski R et al., *Ecological dynamics and motor learning design in sport*, in *Skill Acquisition in Sport: Research, Theory & Practice*, A.M. Williams and N. Hodges, Editors. 2012, Routledge: London. p. 112-30.
8. Davids K, Araujo D. The concept of 'Organismic Asymmetry' in sport science. *J Sci Med Sport* 2010; 13(6):633-640.
9. Vilar L, Araujo D, Davids K et al. The Role of Ecological Dynamics in Analysing Performance in Team Sports. *Sports Med* 2012; 42(1):1-10.
10. Travassos B, Duarte R, Vilar L et al. Practice task design in team sports: Representativeness enhanced by increasing opportunities for action. *J Sport Sci* 2012; 30(13):1447-1454.
11. Passos P, Milho J, Fonseca S et al. Interpersonal Distance Regulates Functional Grouping Tendencies of Agents in Team Sports. *J Motor Behav* 2011; 43(2):155-163.
12. Schöllhorn W. Coordination dynamics and its consequences on sports. *Int J Comp Sci Sport* 2003; 2(2):40-46.
13. Hill-Haas SV, Dawson B, Impellizzeri FM et al. Physiology of Small-Sided Games Training in Football A Systematic Review. *Sports Med* 2011; 41(3):199-220.
14. Hill-Haas SV, Rowsell GJ, Dawson BT et al. Acute physiological responses and time-motion characteristics of two small-sided training regimes in youth Soccer players. *J Strength Cond Res* 2009; 23(1):111-115.
15. Hill-Haas SV, Coutts AJ, Dawson BT et al. Time-Motion Characteristics and Physiological Responses of Small-Sided Games in Elite Youth Players: The Influence of Player Number and Rule Changes. *J Strength Cond Res* 2010; 24(8):2149-2156.
16. Capranica L, Tessitore A, Guidetti L et al. Heart rate and match analysis in pre-pubescent soccer players. *J Sport Sci* 2001; 19(6):379-384.
17. Gabbett TJ. Training injuries in rugby league: An evaluation of skill-based conditioning games. *J Strength Cond Res* 2002; 16(2):236-241.

18. Gabbett TJ. Skill-based conditioning games as an alternative to traditional conditioning for rugby league players. *J Strength Cond Res* 2006; 20(2):309-315.
19. Rampinini E, Impellizzeri FM, Castagna C et al. Factors influencing physiological responses to small-sided soccer games. *J Sport Sci* 2007; 25(6):659-666.
20. Katis A, Kellis E. Effects of small-sided games on physical conditioning and performance in young soccer players. *J Sport Sci Med* 2009; 8(3):374-380.
21. Gamble P. A skill-based conditioning games approach to metabolic conditioning for elite rugby football players. *J Strength Cond Res* 2004; 18(3):491-497.
22. Gregson W. Yhe physiology of football drills. *Insight* 2000; 3(4):1-2.
23. Little T. Optimizing the Use of Soccer Drills for Physiological Development. *Strength Cond J* 2009; 31(3):67-74.
24. Gabbett TJ, Mulvey MJ. Time-motion analysis of small-sided training games and competition in elite women Soccer players. *J Strength Cond Res* 2008; 22(2):543-552.
25. Castellano J, Casamichana D. Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *J Sport Sci* 2010; 28(14):1615-1623.
26. Williams AG, Little T. Effects of sprint duration and exercise: Rest ratio on repeated sprint performance and physiological responses in professional soccer players. *J Strength Cond Res* 2007; 21(2):646-648.
27. Little T, Williams AG. Suitability of soccer training drills for endurance training. *J Strength Cond Res* 2006; 20(2):316-319.
28. Impellizzeri FM, Marcora SM, Castagna C et al. Physiological and performance effects of generic versus specific aerobic training in soccer players. *Int. J. Sports Med.* 2006; 27(6):483-492.
29. Dellal A, Chamari K, Pintus A et al. Heart rate responses during small-sided games and short intermittent running training in elite Soccer players: A comparative study. *J Strength Cond Res* 2008; 22(5):1449-1457.
30. Mallo J, Navarro E. Physcial load imposed on soccer players during small-sided training games. *J Sport Med Phys Fit* 2008; 48(2):166-171.
31. Castagna C, Impellizzeri F, Cecchini E et al. Effects of Intermittent-Endurance Fitness on Match Performance in Young Male Soccer Players. *J Strength Cond Res* 2009; 23(7):1954-1959.
32. Coutts AJ, Rampinini E, Marcora SM et al. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport* 2009; 12(1):79-84.
33. Hill-Haas SV, Coutts AJ, Rowsell GJ et al. Generic versus small-sided game training in soccer. *Int J Sports Med* 2009; 30(9):636-642.
34. Hill-Haas SV, Dawson BT, Coutts AJ et al. Physiological responses and time-motion characteristics of various small-sided soccer games in youth players. *J Sport Sci* 2009; 27(1):1-8.
35. Kellis E, Katis A. Effects of small-sided games on physical conditioning and performance in young soccer players. *J Sport Sci Med* 2009; 8(3):374-380.
36. Hill-Haas S, Coutts A, Rowsell G et al. Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *J Sci Med Sport* 2008; 11(5):487-490.
37. Folgado H, Lemmink K, Frencken W et al. Length, width and centroid distance as measures of teams tactical performance in youth football. *Eur J Sport Sci* 2012; iFirst article:1-6.

CHAPTER 2

A REVIEW ON THE EFFECTS OF SOCCER SMALL-SIDED GAMES

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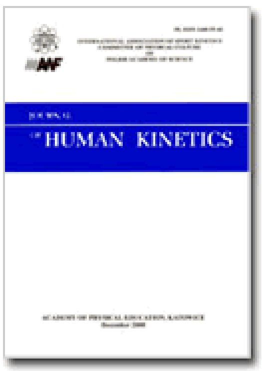
ABSTRACT

Over the last years there has been a substantial growth in research directly related to specific training methods in soccer with a strong emphasis on the effects of small-sided games. The increase of curiosity about this area is coincident with the increase of popularity obtained by specific soccer conditioning, which involves training players to deal with soccer situations on the basis of what is required in a given match situation. Given the limited time available for fitness training in soccer, the effectiveness of small-sided games as a conditioning stimulus needs to be optimized to allow players to compete at the highest level. Available studies indicate that physiological responses (e.g. heart rate, blood lactate concentration and rating of perceived exertion), tactical and technical skill requirements can be modified during small-sided games by altering factors such as the number of players, the size of the pitch, the rules of the game, and coach encouragement. However, because of the lack of consistency in small-sided games design, player fitness, age, ability, level of coach encouragement, and playing rules in each of these studies, it is difficult to make accurate conclusions on the influence of each of these factors separately.

KEY WORDS: soccer, training, conditioning, heart rate, players, technique, perceived exertion



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2.1. INTRODUCTION

Soccer is probably the most popular sport in the world. Despite its universal nature and its formal history extended back over an hundred years, there are still many uncertainties concerning its multidimensional requirements (physiological, psychological, biomechanical) and therefore uncertainties when planning for optimal training and conditioning. In fact, this game is very complex because the pitch is substantially large (approximately 100 x 60 m), the ball is controlled with the feet and head and there may be interactions within eleven teammates and between eleven opponents, almost all with different roles in the game.

Such complexity is currently addressed in training sessions by using specific tasks with the goal of reducing interactions and increasing the ratio of players' participation in decision making, but preserving basic variability properties from the game (Capranica et al., 2001; Gabbett, 2002; Gabbett, 2006; Jones and Drust, 2007; Rampinini et al., 2007; Frencken and Lemmink, 2008; Hill-Haas et al., 2009c, 2010; Katis and Kellis, 2009). These tasks are known as small-sided games (SSG) and its study is currently one of the most addressed topics in soccer contemporary research (Hill-Haas et al., 2009c, 2010).

In high performance sports it has been well documented that the maximum benefits are achieved when the training stimuli are similar to competitive demands (Bompa, 1983). In order to reproduce the physical, technical and tactical requirements of real match play (MacLaren et al., 1988; Miles et al., 1993; Hoff et al., 2002; Reilly and White, 2004; Sassi et al., 2004), coaches often use SSG in their training programs.

SSG started as an optimal task to optimize training time by fulfilling the broad range of fitness requirements without compromising skill performance and decision-making. Therefore, they are used extensively to improve physical fitness levels and also technical and tactical performance in a wide variety of soccer codes (Balsom, 1999; Drust et al., 2000; Gabbett, 2002; Nurmekivi et al., 2002; Bangsbo, 2003; Reilly and Gilbourne, 2003; Gamble, 2004; Eniseler, 2005; Gabbett, 2005; Reilly and White, 2005; Sainz and Cabello, 2005; Sassi et al., 2005; Rampinini et al., 2007; Aguiar et al., 2008; Duarte et al., 2009, Hill-Haas et al., 2008, 2009a,b,c, 2010).

The intensity of these soccer-specific training drills with the ball can be affected or manipulated to provide different physical, technical and tactical responses by several factors, such as, the number of players involved, the size and the shape of the pitch, the duration of exercise and rest periods, the rules of the game, the coach encouragement, the availability of balls or by the way of scoring points (Bangsbo, 1994; Balsom, 2000; Hill-Haas et al., 2009a). A better understanding of the influence of modifying those variables on SSG will assist coaches in controlling the training process with players.

Recent literature has been focused on the physiological and technical aspects of SSG (Impellizzeri et al., 2006; Tessitore et al., 2006; Jones and Drust, 2007; Dellal et al., 2008; Frencken and Lemmink, 2008; Castagna et al., 2009; Couts et al., 2009; Hill-Haas et al., 2009b; Katis and Kellis, 2009). Secondly, the emphasis has been placed on the restrictions of the task that may have effects on the physiological responses to SSG (Rampinini et al., 2007; Kelly and Drust, 2008; Hill-Haas et al., 2008; 2009a, c; 2010).

2.2. RESEARCH

Soccer constitutes an open skill team sport characterized by performance under variable conditions and it can be expected that different aspects of performance might vary according to situational circumstances (Tessitore et al., 2006). Coaches can administer a large variety of drills by changing the size and the shape of the playing area, the number of players, the rules and drill duration. At present, training sessions are focused on enhancing both physiological and technical-tactical aspects of play through general conditioning bouts and training drills.

In the last years, with the increased use of SSG as a training method, the scientific community devoted them greater attention. In fact, we found recent studies with conclusions which suggest that physiological responses (e.g. heart rate, blood lactate concentration and rating of perceived exertion) and technical/skill requirements can be modified during SSG in soccer by altering factors such as the number of players, the size of the pitch, the rules of the game, and coach encouragement (Casamichana and Castellano, 2010; Grant et al., 1999a; Grant et al., 1999b; Little and Williams, 2006; 2007; Owen et al., 2004; Platt et al., 2001; Impellizzeri et al., 2006; Tessitore et al., 2006; Jones and Drust, 2007; Rampinini et al., 2007; Williams and Owen, 2007; Barbero-Álvarez et al., 2008; Dellal et al., 2008; Gabbett and Mulvey, 2008; Kelly and Drust, 2008; Mallo and Navarro, 2008; Castagna et al., 2009; Coutts et al., 2009; Hill-Haas et al., 2008, 2009a,b,c; 2010; Katis and Kellis, 2009).

This review systematizes the SSG use as a training method and highlights the main restrictions of its application in soccer. All factors affecting the SSG are analyzed separately according to studies conducted in order to understand its importance in the response of athletes to training. Despite this division to facilitate the comprehension of these factors, we must take into account that the interaction may affect the final response of athletes. This review also aims to focus on new features of the SSG, still little studied, and because of its great importance, they deserve the attention of researchers. A deeper understanding about the influence of manipulating those variables on SSG will assist coaches in controlling the training process.

2.2.1. Number of players

Recent studies have shown that SSG formats with a different number of players elicit different physiological, perceptual, and time-motion characteristics (Aroso et al., 2004; Hill-Haas et al., 2009a; 2010; Katis and Kellis, 2009; Sampaio et al., 2007; Owen et al., 2004; Rampinini et al., 2007). It is also common for coaches to use SSG formats that involve a team playing with a fixed numerical advantage against another team with a fixed numerical disadvantage, as used by Hill-Haas et al. (2010). In general, these studies have shown that SSG formats with fewer players elicit greater heart rate than the larger formats (Hill-Haas et al., 2009a, 2010; Impellizzeri et al., 2006; Katis and Kellis, 2009; Little and Williams, 2006, 2007; Owen et al., 2004; Rampinini et al., 2007). However, some authors reported a different conclusion (Aroso et al., 2004; Dellal et al., 2008; Hill-Haas et al., 2008; Hoff et al., 2002; Jones and Drust, 2007; Sampaio et al., 2007) because no differences were found in heart rate responses between SSG formats. Based on the results presented in the aforementioned studies, different SSG formats elicit different heart rate values (see Table 2.1).

Variability among different SSG is confirmed by Hill-Haas et al. (2008) who found a typical error less than 5% across the different SSG results.

Fewer studies have focused on the effect of SSG formats on the lactate threshold. However, these studies are more consensual and showed that SSG formats with fewer players elicit greater lactate thresholds (Hill-Haas et al., 2008, 2009a; Impellizzeri et al., 2006; Rampinini et al., 2007).

The rating of perceived exertion (RPE) to the player number changes is in accordance with those found to heart rate responses. In general, these studies have shown that SSG formats with fewer players elicit greater RPE than the larger formats (Aroso et al., 2004; Hill-Haas et al., 2008, 2009a, 2010; Impellizzeri et al., 2006; Rampinini et al., 2007).

Table 2.1 – Maximal heart rate values according to different SSG formats.

SSG Format	% HR_{max} Range	Reference
1-a-side	75 – 80	Dellal et al., 2008
2-a-side	88 – 91	Hill-Haas et al., 2009a; Little and Williams, 2006
3-a-side	87-90	Katis and Kelis, 2009; Litle and Williams, 2006; Rampinini et al., 2007
4-a-side	85-90	Hill-Haas et al., 2009a; Litle and Drust, 2008; Litle and Williams, 2006; Rampinini et al., 2007
5-a-side	82-87	Hill-Haas et al., 2009c; Litle and Williams, 2006; Rampinini et al., 2007
6-a-side	83-87	Hill-Haas et al., 2009c; Katis and Kelis, 2009; Little and Williams, 2006; Rampinini, 2007

The effect of the SSG formats in the technical requirements was addressed by two studies (Jones and Drust, 2007; Katis and Kellis, 2009), suggesting that the number of players should be carefully considered by coaches in their organization. The authors suggested that SSG with small number of players can deliver a more effective technical training stimulus, since the number of technical actions increases with the decrease of players' number.

The work-rate profiles of players were also observed taking into account the number of players involved (Jones and Drust, 2007; Hill-Haas et al., 2008, 2009a, 2010). The results found are consensual, with most authors claiming that no significant differences were observed in either total distance covered or the total distance covered by walking or jogging. Nevertheless, there is no consensus at high intensity efforts. Hill-Haas et al. (2010) have not found any differences between the amount of players involved in games. Jones and Drust (2007) suggested that high intensity efforts are increased when the number of players is reduced. This conclusion was firstly supported by Platt et al. (2001). The opposite was suggested by Hill-Haas et al. (2008), when these authors observed in their research that maximal and mean sprint duration and distance were increased with the amount of players involved.

These previous studies have only examined the influence of altering the player numbers on teams maintaining a numerical balance between opposing teams (e.g., 2 vs. 2 players and 4 vs. 4 players). It is usual for coaches to use SSG formats that involve a team playing with a fixed numerical advantage against another team with a fixed numerical disadvantage (e.g., 4 vs. 3 players and 6 vs. 5). It is also common to use SSG formats that involve variable ‘‘overload’’ and ‘‘underload’’ situations, which are achieved using a ‘‘floater’’ player. Hill-Haas et al. (2010) studied the response of athletes to this and they concluded that despite fixed underload teams recording a significantly higher RPE compared with the fixed overload teams, there were no differences in time-motion characteristics and physiological responses. According to these authors, both formats (fixed and variable) may provide a useful variation in SSG training or as a technical-tactical training method for defensive and attacking plays. The possibility of variable formats proving a greater technical load needs to be substantiated by further research. Finally, the use of a floater appears to be more effective in smaller format games and may be appropriate for either maintaining or developing aerobic fitness.

The different conclusions may be due to the fact that the methodology adopted by the authors and the population that served as a sample study were distinct. Another fact that may have led to such different conclusions is the difficulty found to isolate all the factors which can contribute to the physiological and technical response of players. Finally, another possible reason for discrepant results includes the fact that the pitch size masks the effects of variations in the number of players.

2.2.2. Pitch size

Research has shown that using different pitch dimensions and formats can elicit different physiological and perceptual responses, as well as time-motion activity. However, studies are not consensual on the influence of the pitch size in the physiological response of the players. In the origin of this disagreement is probably the fact that research has been carried using several different pitch sizes (see Table 2.2).

According to Tessitore et al. (2006) coaches can modulate training intensity by varying pitch dimension, with smaller individual area having a large impact on metabolic demands of exercise. In this study, the exercise intensity ranged from 61% to 76% of the players maximal oxygen uptake, with lower values for the larger pitch. These results are similar to those obtained by Kelly and Drust (2008), as the authors did not find different heart rate responses between SSG played in three pitch dimensions. On the contrary, Rampinini et al. (2007) and Casamichana and Castellano (2010) found significant differences in heart rate responses between SSG played on pitches with different sizes. Higher HRs during SSG played on a large pitch was registered when compared to medium-sized and smaller ones.

Table 2.2 -Ranges of pitch area (m^2) used in each SSG format.

SSG format	Pitch size used (m^2)		Reference
	Min.	**Max.**	
1x1	100		(Dellal et al., 2008)
2x2	400	800	(Dellal et al., 2008) (Hill-Haas et al., 2009b)
3x3	240	2500	(Rampinini et al., 2007) (Gabbett and Mulvey, 2008)
4x4	384	2208	(Coutts et al., 2009)
5x5	580	2500	(Coutts et al., 2009) (Gabbett and Mulvey, 2008)
6x6	768	2400	(Coutts et al., 2009) (Hill-Haas et al., 2009b)
7x7	875	2200	(Hill-Haas et al., 2009b)
8x8	2400	2700	(Jones and Drust, 2007) (Dellal et al., 2008)

Blood lactate variation due to different pitch sizes suggests that drills played in a bigger pitch resulted in a more aerobic activity with a higher occurrence of intensities up to the lactate threshold (Tessitore et al., 2006, Rampinini et al., 2007). In their study, Tessitore et al. (2006) concluded that 6-a-side drills played on the bigger pitch resulted in a greater aerobic activity with a higher impact occurrence of intensities up to lactate threshold (50 x 40 m pitch: 3 min 85%; 8 min: 65%) with respect to the smaller pitch (30 x 40 m pitch: 3 min 50%; 8 min: 39%). Those results were corroborated by Rampinini et al. (2007) who found higher blood lactate values during different small-sided games forms played on a larger pitch than on medium-sized and small ones.

RPE have a multifactorial nature, which is mediated not only by physiological but also by psychological factors (Borg et al., 1987; Morgan, 1994). This may cause a large variability among subjects, and is one of the limitations to drawing of conclusions about the effect of the SSG pitch area in the RPE. Only in the studies conducted by Rampinini et al. (2007) and Casamichana and Castellano (2010) addressed the specific effect of pitch dimension on the RPE. The authors found differences between medium and large pitches, both of which resulted in higher RPE ratings relatively to smaller pitches. Analyzing these findings together with those obtained in previous studies not specific about the effect of the play area in the RPE, it seems that increasing the ratio between the area x player reduces player perception of effort in SSG training (Hill-Haas et al., 2009a). Casamichana and Castellano (2101) found that the effective playing time could offer a potential explanation for the differences in the physiological, physical and perceived exertion variables studied in SSG: as the individual playing area was reduced, the frequency of motor behaviors increased, with a concomitant decrease in effective playing time (since a greater number of rule-related interruptions leads to a shorter effective playing time). At the same time, the players cover less ground, spending more time stationary or walking, which leads to a lower physiological workload and lower ratings of perceived exertion.

Some authors also looked to the influence of the pitch size in the technical actions and they found no significant differences in the frequency of most actions, such as passing, receiving, dribbling, interceptions or headings (Tessitore et al., 2006; Kelly and Drust, 2008). However, Kelly and Drust (2008) found a high number of shots and tackles in the smaller pitches. This conclusion was supported by the data obtained by Owen et al. (2004). The increase of tackles in smaller SSG pitch sizes may be due to smaller area per player, which causes a greater proximity to the opponents and hence greater physical contact. On the other side, the increasing number of shots can be justified by the proximity of goals, which can lead soccer players make more frequent attempts at the goal. According to Kelly and Drust (2008), this would suggest that pitch size should only be carefully considered by coaches in their organization of practice if the drill is required to combine a physical training stimulus with technical work on shooting or if minimal physical contact in training is the objective.

Previous studies allow us to conclude that there is no consensus about the influence that pitch size changing has on the physiological responses of athletes. However, these studies are in agreement stating that this factor has no significant influence on technical demands. The different conclusions reached in the performed studies about physiological demands can be due to different methodologies. For example, Tessitore et al. (2006) and Rampinini et al. (2007) did not examine the isolate impact of the key independent variables, such as exercise type, pitch dimension, coach encouragement. As a consequence, their studies are limited in its ability to clearly differentiate the impact of specific variables on the physiological responses to SSG. Moreover, by altering pitch size we can regulate the athlete’s effort intensity in SSG training. According to reports from players and coaches when the ratio of the playing area and number of players is increased, exercise intensity increases as well (Rampinini et al., 2007). This might be explained by the increased playing area that each player has to cover, which means more displacement and probably movements with higher speed. For example, Balsom (1999) suggested that during four-a-side games, intensity similar to that in three-a-side games could be reached by increasing the playing area.

In general, the variation found in the pitch areas of the same SSG format does not allow us to draw definitive conclusions about the effect of the pitch size on the player's response. To overcome this problem, sport researchers should define to each SSG form a standard area to perform their studies, and define, to the same SSG format what should be a small, medium or large area. In our opinion, only with standardized pitch sizes and methodologies we are able to isolate the specific effect of pitch size on athletes from the other factors (*e.g.* number of players, coach encouragement, etc.).

2.2.3. Presence of goalkeepers and goals

The presence or absence of a goalkeeper in the SSG has some effect on players' physiological and technical responses. Mallo and Navarro (2008) suggested that the inclusion of a goalkeeper modified the physiological and tactical behavior of the players. The authors found lower heart rates in the game with goalkeepers than in the two games without goalkeepers. These results were not confirmed by Dellal et al. (2008), who found an increase of 10.7% in residual heart rate in the 8-a-side game with goalkeepers. However, the authors found a lower game intensity when the goalkeepers were present. In accordance with the heart rate results, Mallo and Navarro (2008) found exercise intensities higher in the drill performed without goalkeepers. On the other hand, the same authors found a predominance of medium-intensity activities in the drills with goalkeepers. When the technical parameters were analyzed according to presence of goalkeepers, Mallo and Navarro (2008) found lower frequencies of actions with the ball.

These contradictory results can be explained by the fact that the studies did not specifically address the effect of the presence of goalkeepers in the SSG. The inclusion of a goalkeeper probably changed the physiological and tactical behavior of the players (Mallo and Navarro, 2008) because it is possible that some players are more motivated than others by their presence (Dellal et al., 2008). In fact, the aims of scoring and simultaneously protecting their own goalkeepers may have imposed a greater activity on the soccer players (Allen et al., 1998; Dellal et al., 2008; Spalding et al., 2004; Stolen et al., 2005). When playing with goalkeepers, the players will be probably more organized defensively in order to protect their goal, which had a repercussion in game intensity.

2.2.4. Absence / presence of goals or mini-goals

The intensity of the soccer SSG can be affected by many factors such as the way of scoring (Bangsbo, 1994; Balsom, 2000; Mallo and Navarro, 2008) and the aim of the game (scoring goals or maintaining ball possession). Despite this fact, we have not found a study about the effect of these variables on the physiological and technical response of players during SSG.

2.2.5. Presence / absence of coach encouragement

Coach encouragement is referred by many authors as one of the factors that influence the player's physiological response to SSG (Bangsbo, 1998; Balsom, 1999; Couts et al., 2004; Hoff et al., 2002; Mazzetti et al., 2000; Rampinini et al., 2007). This effect could be very important from a practical point of view because the external motivation provided by coach supervision has been shown to achieve greater gains and training adherence, for example, during resistance training (Couts et al., 2004; Mazzetti et al., 2000; Rampinini et al., 2007).

Despite the recognition of its importance, only Rampinini et al. (2007) addressed these effects and found higher heart rates, blood lactates and RPE when the coaches provided encouragement during the SSG. According to the authors, the mean intensity of all SSG included in their study is within the range classified as "high" by Bangsbo (2003). Based on effect size comparisons, the factor that had the greatest influence on the physiological responses to SSG was encouragement, followed by exercise type and field dimensions.

2.2.6. Rule changes /task constraints

It is also common for coaches to modify the task constraints of SSG in order to change the physical and technical loads imposed on players. Examples of these SSG modifications include restricting the number of ball touches per player or team, implementing (or not) offside rules, changing players to create superiority or inferiority in confronting teams, or alter the goals position in the pitch.

Hill-Haas et al. (2010) studied the influence of rule changes in the time-motion characteristics and physiological responses during SSG played by elite youth players. The author introduced five conditions in the games: 1) offside rule in effect (front one-third zone of the pitch); 2) kick in only (ball cannot be thrown in if it leaves the grid); 3) all attacking team players must be in front 2 zones for a goal to count; 4) alongside, but outside the lengths of each pitch, 2 neutral players can move up and down the pitch but not enter the grid; and, 5) 1 player from each team (‘‘a pair’’) completes 4 repetitions of ‘‘sprint the widths/jog the lengths’’ on a 90-second interval. The combination of these conditions constitutes the 4 rules applied to the game (example: rule 1 – respect the condition 1+2).

The results obtained by the authors showed that the artificial rule change which required the players to sprint the widths and jog the lengths of the pitch (condition 5) had a greater effect on the time-motion characteristics (total distance traveled, higher intensity running, and number of sprints) than all other rule modifications. However, this artificial rule change had no influence on blood lactate and RPE. According to the author, one possible reason for this may be a “pacing effect” because the relatively long duration of the game, can reduce the rhythm of play, and thereby the physiological and perceptual load, as a strategy to endure the game (Carling and Bloomfield, 2010).

In contrast, a technical rule change requiring that all players from the attacking team to be in the last two-thirds of the pitch for a score to count (condition 3) increased %HR_{max} and blood lactate in both small and large game formats. Despite the duration of the game, this rule change may not have induced a significant pacing strategy because scoring a goal would not have elicited large increases in total distance covered. These results suggest that technical rules that are related to a team’s chance of scoring a goal may influence the player’s motivation to increase or maintain exercise intensity and therefore enhance the player’s physiological response to SSG. Both the technical and the artificial rule changes used in this study had no effect on RPE. The results obtained by the authors are in contrast to previous studies that reported an increase in blood lactate (player-to-player marking) (Aroso et al., 2004), RPE (maximum of 2 touches on the ball) (Sampaio et al., 2007), and %HR_{max} (pressure half switch) (Little and Williams, 2006) with specific rule changes during SSG.

It seems clear that changes in task constraints SSG playing rules can influence and modify the physiological, perceptual and time-motion responses. However, we suggest that rule changing and variations in technical variables in SSG requires further investigation.

2.2.7. Continuous *vs* intermittent training

SSG are both reliable and effective for the technical and tactical development of soccer players. However, few studies have examined how the intensity of SSG can be manipulated to alter training stimulus (Fanchini et al., 2011; Hill-Haas et al., 2009c). In soccer, SSG training is typically completed in the form of "intervals" as opposed to continuous duration play, which is more typical of actual game play. However, we found only two studies that focused on the influence or additional benefits of interval or continuous SSG training. In fact, Hill-Haas et al. (2009c) examined the acute physiological responses and time-motion characteristics associated with continuous and intermittent SSG training regimens. The same conclusion was reached by Fanchini et al. (2011). The authors found a significantly lower heart rate in a bout with 2 minutes duration than in bouts with 4 and 6 minutes. The results suggested that continuous SSG elicited a significantly higher percentage of maximum heart rate response compared with intermittent SSG. The additional rest period between work-bouts during intermittent SSG can be the possible explanation. Other possible reason for these results may be a pacing effect, because the relatively long duration of the game in continuous SSG can lead players to reducing the rhythm of play, and thereby the physiological and perceptual load, in order to endure the game (Carling and Bloomfield, 2010).

The percentage of maximum heart rate response for intermittent SSG are similar to those previously obtained in small-formats (Aroso et al., 2004; Owen et al., 2004; Sampaio et al., 2007). The percentage of maximum heart rate response values found with continuous SSG format are similar to those reported for larger format intermittent games (Little and Williams, 2007; Owen et al., 2004; Rampinini et al., 2007). On the other side, no significant differences were found in the lactate threshold between intermittent and continuous SSG training. These results are similar to those obtained in other intermittent SSG studies (Aroso et al., 2004; Rampinini et al., 2007).

Fanchini et al. (2011) found no significant differences in RPE responses between the three different bouts (2, 4 and 6 minutes). These results were not confirmed by Hill-Haas et al. (2009c). In their study, the authors concluded that continuous SSG elicited a significantly higher RPE response compared with intermittent SSG. These results suggest that higher RPE values are associated with very short intermittent playing durations, which implies that players are able to perform at very high intensity for only short durations during intermittent SSG training. The RPE values obtained by Hill-Haas et al. (2009c) and Fanchini et al. (2011) during intermittent SSG were lower than those previously reported by Aroso et al. (2004) and Sampaio et al. (2007). A possible explanation is the different intermittent playing durations applied in particular studies.

Hill-Haas et al. (2009c) have not divided the time motion results into intermittent and continuous covered distances. However, players covered greater distance between 13.0 and 17.9 km.h^{-1} and at speeds above 18.0 km.h^{-1} during intermittent SSG when compared with continuous SSG. Additionally, the players completed a higher number of sprints and had a higher sprint ratio in intermittent SSG when compared with continuous SSG. One possible explanation to those results was the additional passive rest period between each interval bouts which may have allowed a greater physiological recovery.

Fanchini et al. (2011) also studied the effect of bout duration on technical performance and significant statistical differences between bouts were not found. However, the authors found a tendency to a decrease in total passes, successful passes and interceptions in the bout with highest duration. This fact may suggest that bouts with largest duration may cause a decrease in technical proficiency.

2.3. CONCLUSIONS

In SSG the players experience similar situations that they encounter in competitive matches (Owen et al., 2004). Due to this fact, game-based conditioning using SSG has become a popular method of developing specific aerobic fitness for soccer players (Impellizzeri et al., 2006). Despite the increasing popularity of SSG, not many research has examined how the intensity of SSG can be manipulated to alter training stimulus (Hill-Haas et al., 2009c). Research was focused on evaluating physiological, tactical and technical responses of athletes when factors such as a number of players, the size of the pitch, rules of the game, and coach encouragement were modified in SSG. The studies appear to confirm that by altering these factors we can manipulate the overall physiological and perceptual workload.

Across the presented studies, we conclude that by changing factors such as a number of players, pitch size, presence/absence of goalkeeper and goals, coach encouragement and the rules, coaches can manipulate the effect of SSG drills on soccer players. However, because of the lack of consistency in SSG design, player fitness, age, ability, level of coach encouragement, and playing rules among the studies, it is difficult to make accurate conclusions on the influence of each of these factors separately. Due to this limitation, SSG management requires further investigation. The use of standardized conditions in SSG studies will probably allow a better understanding about the role of individual factors and may help researchers to find more reliable conclusions.

2.4. REFERENCES

Aguiar M. Abrantes C. Maçãs V. Leite N. Sampaio J. Ibáñez, S. Effects of intermittent or continuous training on speed, jump and repeated-sprint ability in semi-professional soccer players. *Op Sports Sci J.* 2008, 1, 15-19.

Allen JD. Butterfly R. Welsh MA. Wood R. The physical and physiological value of 5-a-sided soccer training to 11-a-side match play. *J Hum Mov Studies.* 2005, 34, 1-11.

Aroso J. Rebelo AN. Gomes-Pereira J. Physiological impact of selected game-related exercises. *J Sports Sci,* 2004. 22, 522.

Balsom P. *Precision Football*. Kempele, Finland: Polar Electro Oy, 1999.

Balsom P. *Precision Football*. Kempele, Polar Electro Oy, 2000.

Bangsbo, J. The physiology of soccer – with special reference to intense intermittent exercise. *Acta Physiol Scan.* 1994, 15 (Suppl. 619), 1-156.

Bangsbo J. Optimal preparation for the world cup in soccer. *Clin Sports Med.* 1998. **17**, 697-709.

Bangsbo, J. Physiology of training. In: *Science and Soccer*. Ed: Reilly T. Williams AM. London: UK: Routledge. 2003, 47-58.

Barbero-Álvarez JC. Soto VM. Barbero-Álvarez V. Granda-Vera J. Match analysis and heart rate of futsal players during competition. *J Sports Sci*, 2008. 26, 63-73.

Bompa, T. (1983) *Theory and methodology of training*. Dubusque, Iowa: Kendall/Hunt.

Borg G. Hassmen P. Lagerstrom M. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *Eur J App Physiol Occup Physiol,* 1987. 56, 679-685.

Capranica L. Tessitore A. Guidetti L. Figura F. Heart rate and match analysis in pre-pubescent soccer players. *J Sports Sci,* 2001. 19, 379-384.

Carling C. Bloomfield J. The effect of an early dismissal on ensuing player work-rate in a professional soccer match. *J Sports Sci Med,* 2010. 13(2), 126-128.

Casamichana D. Castellano J. Time-motion, heart rate, perceptual and motor behavior demands in small-sides soccer games: effects of pitch size. *J Sports Sci,* 2010. 28(14), 1615 - 1623.

Castagna C. Impelizzeri F. Cecchini E. Rampinini E. Alvarez JCB. Effects of intermittent-endurance fitness on match performances in youth male soccer players. *J Stren Cond Res,* 2009. 23(7), 1954-1959.

Coutts AJ. Murphy AJ. Dascombe BJ. The effect of direct supervision of a strength coach on measures of muscular strength and power in young rugby league players. *J Stren Cond Res,* 2004. 18(2), 157-164.

Coutts AJ. Rampinini E. Marcora SM. Castagna C. Impellizzeri FM. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport.* 2009, 12, 79-84.

Dellal A. Chamari K. Pintus A. Girard O. Cotte T. Keller D. Heart rate responses during small-sided and short intermittent running training in elite soccer players: a comparative study. *J Stren Cond Res,* 2008. 22(5), 1449-1457.

Drust B. Reilly T. Cable NT. Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. *J Sports Sci,* 2000, **18,** 885-892.

Duarte R. Batalha N. Folgado H. Sampaio J. Effects of exercise duration and number of players in heart rate responses and technical skills during Futsal small-sided games. *Op Sports Sci J,* 2009. 2, 37-41.

Eniseler N. Heart rate and blood lactate concentrations as predictors of physiological load on elite soccer players during various soccer training activities. *J Stren Cond Res,* 2005. 19, 799–804.

Fanchini M. Azzalin A. Castagna C. Schena F. Mcall A. Impellizzeri F. Effect of bout duration on exercise intensity and technical performance of small-sided games in soccer. *J Stren Cond Res,* 2011. 25, 453-458.

Frencken W. Lemmink K. Team kinematics of small-sided soccer games: A systematic approach. In: *Science and football VI*. Ed: Reilly T. Korkusuz F. New York, NY: Routledge. 2008, 161-166.

Gabbett T. Mulvey M. Time-motion analysis of small-sided training games and competition in elite women soccer players. *J Stren Cond Res,* 2008. 22(2), 543-552.

Gabbett TJ. Training injuries in rugby league: an evaluation of skill-based conditioning games. *J Stren Cond Res,* 2002. 16, 236–41.

Gabbett TJ. Science of rugby league soccer: a review. *J Sports Sci, 2005.* 23, 961-976.

Gabbett TJ. Skill-based conditioning games as an alternative to traditional conditioning for rugby league players. *J Stren Cond Res,* 2006. 20, 309–314.

Gamble PA. Skill-based conditioning games approach to metabolic conditioning for elite rugby soccer players. *J Stren Cond Res,* 2004. 18, 491-497.

Grant A, Williams M, Dodd R, Johnson S. Physiological and technical analysis of 11 v 11 and 8 v 8 youth football matches. *Insight,* 1999a. 2, 3-4.

Grant A, Williams M, Johnson S. Technical demands of 7 v 7 and 11 v 11 youth football matches. *Insight,* 1999b. 2, 1-2.

Hill-Haas S. Coutts A. Rowsell G. Dawson B. Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *J Sci Med Sport,* 2008. 11, 487-490.

Hill-Haas S. Dowson BT. Couts AJ. Rowsell GJ. Physiological responses and time-motion characteristics of various small-sided soccer games in youth players. *J Sports Sci,* 2009a. 27(1), 1-8.

Hill-Haas S. Couts A. Rowsell G. Dawson B. Generic versus small-sided game training in soccer. *Int J Sports Med.* 2009b, 30(9), 636-642.

Hill-Haas SV. Rowsell GJ. Dawson B. Coutts AJ. Acute physiological responses and time-motion characteristics of two small-sided training regimes in youth soccer players. *J Stren Cond Res,* 2009c. 23(1), 111-115.

Hill-Haas SV. Dowson BT. Couts AJ. Rowsell GJ. Time-motion characteristics and physiological responses of small-sided games in elite youth players: the influence of player number and rule changes. *J Stren Cond Res,* 2010. 24(8), 2149-2156.

Hoff J. Wisløff U. Engen LC. Kemi OJ. Helgerud J. Soccer specific aerobic endurance training. *Brit J Sports Med.* 2002, 36(3), 218-221.

Impellizzeri FM. Marcora SM. Castagna C. Reilly T. Sassi A. Iaia FM. Rampinini E. Physiological and performance effects of generic versus specific aerobic training in soccer players. *Int J Sports Med,* 2006. 27, 483-492.

Jones S. Drust B. Physiological and Technical Demands of 4 v 4 and 8 v 8 games in elite youth soccer players. *Kinesiology.* 2007, 39(2), 150-156.

Katis A. Kellis E. Effects of small-sided games on physical conditioning and performance in young soccer players. *J Sports Sci Med.* 2009. 8, 374-380.

Kelly DM. Drust B. The effect of pitch dimensions on heart rate responses and technical demands of small-sided soccer games in elite players. *J Sci Med Sport.* 2008. 12(4), 475-479.

Little T. Williams AG. Suitability of soccer training drills for endurance training. *J Stren Cond Res,* 2006. 20, 316-319.

Little T. Williams A. Measures of exercise intensity during soccer training drills with professional soccer players. *J Stren Cond Res,* 2007. 21, 367-371.

MacLaren D. Davids K. Isokawa M. Mellor S. Reilly T. Physiological strain in 4-a-side soccer. In: *Science and football*. Ed: Reilly T. Lees A. Davids K. Murphy WJ. London: E & FN Spon. 1985, 76-80.

Mallo J. Navarro E. Physical load imposed on soccer players during small-sided games. *J Sports Med Phys Fitness.* 2008, 48(2), 166-171.

Mazzetti SA. Kraemer WJ. Volek JS. Duncan ND. Ratamess NA. Gomez AL. Newton, RU. Häkkinen K. Fleck SJ. The influence of direct supervision of resistance training on strength performance. *Med Sci Sports Exerc*, 2000. 2(6), 1175-84.

Miles A. MacLaren D. Reilly T. Yamanaka K. An analysis of physiological strain in four-a-side women's soccer. In: *Science and Football II*. Ed: Reilly T. Clarys J. Stibbe, A. London: E & FN Spon. 1995, 140-145.

Morgan WP. Psychological components of effort senses. *Med Sci Sports Exerc*, 1994. 26, 1071-1077.

Nurmekivi A. Karu T. Pihl E. Jurimae T. Kaarna K. Kangasniemi J. Comparative evaluation of the influence of small game 4 vs. 4 and running load in the training of young soccer players. *Acta Kinesi Univ Tart*, 2002. 7, 77–86.

Owen A. Twist C. Ford P. Small-sided games: The physiological and technical effect of altering pitch size and player numbers. *Insight*. 2004. 7, 50–53.

Platt D. Maxwell A. Horn R. Williams M. Reilly T. Physiological and technical analysis of 3 v 3 and 5 v 5 youth football matches. *Insight*. 2001. 4, 23–25.

Rampinini E. Impellizzeri FM. Castagna C. Abt G. Chamari K. Sassi A. Marcora SM. Factors influencing physiological responses to small-sided soccer games. *J Sports Sci*, 2007. 25(6), 659-666.

Reilly T. Gilbourne D. Science and football: a review of applied research in the football codes. *J Sports Sci*, 2003. 21, 693-705.

Reilly T. White C. Small-sided games as an alternative to interval-training for soccer players. *J Sports Sci*, 2004. 22, 559.

Reilly T. White C. Small-sided games as an alternative to interval training for soccer players. In: *Science and Soccer V*. Ed: Reilly T. Cabri J. Araújo D. New York: Routledge, 2005. 344–347.

Sainz JM. and Cabello EN. Biomechanical analysis of the load imposed on under-19 soccer players during some typical soccer training drills. In: *Science and Soccer V*. Ed: Reilly T. Cabri J. Araújo D. London: Routledge. 2005, 353–356.

Sampaio J. Garcia G. Maças V. Ibanez J. Abrantes C. Caixinha P. Heart rate and perceptual responses to 2x2 and 3x3 small-sided youth soccer games. *J Sports Sci Med*, 2007. 6(suppl. 10), 121-122.

Sassi R. Reilly T. Impellizzeri F. A comparison of small sided games and interval training in elite professional soccer players. *J Sports Sci*, 2004. 22, 562.

Sassi R. Reilly T. Impellizzeri F. A comparison of small-sided games and interval training in elite professional soccer players. In: *Science and Soccer V*. Ed: Reilly, T., Cabri, J. and Araújo, D. London: Routledge. 2005, 341–343.

Spalding TW. Lyon LA. Steel DH. Hatfield BD. Aerobic exercise training and cardiovascular reactivity to physiological stress in sedentary young normotensive men and women. *Psychophysiology*. 2004, 41, 552-562.

Stolen T. Chamari K. Castagna C. Wisloff, U. Physiology of soccer. *Sports Med*. 2005. 35, 501-536.

Tessitore A. Meeusen R. Piacentini MF. Demarie S. Capranica L. Physiological and technical aspects of "6-a-side" soccer drills. *J Sports Med Phys Fitness*. 2006, 46(1), 36-42.

Williams K. Owen A. The impact of player numbers on the physiological responses to small-sided games. *J Sports Sci Med*. 2007, 6(suppl. 10), 100.

CHAPTER 3

PHYSIOLOGICAL RESPONSES AND ACTIVITY PROFILES OF FOOTBALL SMALL-SIDED GAMES

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ABSTRACT

The aim of this study was to identify the acute physiological responses and activity profiles of football small-sided games (SSG) formats. Ten professional football players participated in four variations of SSG (2-, 3-, 4- and 5-a-side) with an intermittent regime involving 3 × 6 minute bouts with 1 minute of passive planned rest in which the heart rate (30), rating of perceived exertion (40), activity profile and body load were recorded. The higher % HRmax values were found in 2- and 3-a-side formats ($p \leq 0.05$). The lowest RPE value was found at the 5-a-side and the highest was found at the 3-a-side (13.48 ± 2.67 and 17.01 ± 1.80, respectively, $p \leq 0.05$). The distance covered in the 2-a-side format (598.97 ± 78.91 m) was smaller than in all other formats. The 2-a-side format presented the lowest number of sprints (0.71 ± 0.86) and the 3-a-side the highest (2.50 ± 1.65). Statistically significant differences were found across SSG in the total body load. The 4-a-side presented the highest and the 5-a-side the lowest values (95.18 ± 17.54 and 86.43 ± 14.47, respectively). The body load per minute declined each 2 minutes of play. Maintaining a constant area:player ratio, coaches can use lower number of players (2- and 3-a-side) to increase cardiovascular effects, but use higher number of players (4- and 5-a-side) to increase variability and specificity according to the competition demands.

Key Words: football, conditioning, activity profile analysis, body load, small-sided games

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3.1. INTRODUCTION

Small-sided games (SSG) are widely used by football coaches at all levels of the game to develop technical, tactical abilities and physical conditioning of players (17, 33). Recent research suggests that physiological, perceptual (e.g. heart rate, blood lactate and perceived exertion) and technical responses can be modified during SSG in football by modifying game constraints such as the number of players, the size of the pitch, the rules of the game, or coach encouragement (8, 11, 13, 16-20, 24, 28, 33). In general, these studies have shown that SSG formats with fewer players elicit higher heart rate (30) values than SSG formats with higher number of players (18, 19, 24-26, 33, 36). However, some authors have reported no differences between SSG formats (13, 17, 21, 36).

Currently, the use of Global Positioning System technology allows a faster gathering of time-motion data and in higher quantities, contributing to the increase of information regarding SSG responses. The validity and reliability of commercial available GPS receivers have already been established and described (9, 12, 14, 22, 27, 32) allowing the increase of the accuracy of game-related conditioning activities (5, 10, 29). The GPS devices have an acceptable validity and reliability for recording movement patterns at lower speeds and higher sample rates over longer efforts. However, there is a lower accuracy when assessing movement during rapid variations in speed over short distances (22).

Research on time motion analysis of SSG using GPS devices is very recent. One study is available and examines the acute physiological and perceptual responses and the activity profile during SSG in three formats (2-, 4- and 6-a-side) involving youth football players (19). The authors used a constant ratio of player number to pitch area in the different SSG formats. The results showed increases in physiological and perceptual workload as SSG formats decrease in size while maintaining the relative pitch area constant. Another study was performed with elite women players and focused on describing the activity profiles of two different SSG formats (3- and 5-a-side) in comparison with competition (16). The authors concluded that SSG simulate the overall movement patterns of women's football competition, but offered an insufficient training stimulus to simulate the high intensity, repeated-sprint demands of competition.

The use of some commercially available GPS units with incorporated triaxial accelerometers allow the measurement of the body load associated with game play (3). Montgomery and colleagues (31) used these devices to study the physical demands of the basketball training and competition and showed that these data, in combination with HR, can be useful to differentiate the physical and physiological demands during basketball practice and competition. In football, Casamichana *et al.* (7) identified a body load per minute of 15.8 ± 2.7 when playing 3, 5 and 7-a side SSG formats on different pitch layouts (without goals, with 2 regulation goals and goalkeepers, and with 2 small goals, but no goalkeepers). The authors presented this as the overall result and did not compare the different SSG formats. Also, an interesting topic to add to this study would be to compare body load per minute across the duration of play in order to identify different patterns associated with different SSG.

A recent literature review (10) has identified that very few studies have examined the influence of the concurrent manipulation of the pitch area and SSG intensity of player numbers. Additionally, other important aspects were not considered in the previous studies, such as the influence of pitch size and player numbers in the relative pitch area, and these two factors were regularly changed throughout the studies (6, 7, 17, 23, 31-33). Only one study is available with a constant area:player ratio focusing only on 2-, 4- and 6-a side SSG formats in players under 17 years (19). Therefore, the aim of this study was to examine the acute physiological responses, activity profile and body load of four football SSG formats (2-, 3-, 4- and 5-a-side) while maintaining the pitch size per player constant.

3.2. METHODS

3.2.1. Experimental approach to the problem

Few studies have examined the HR responses, rating of perceived exertion, activity profile characteristics and body load of four different SSG formats keeping the area per player constant (10). In this study, four SSG formats were used (2-, 3-, 4- and 5-a-side players) with an intermittent regime involving 3 × 6 – minute bouts with 1 minute of passive planned rest (work:rest ratio = 6:1). This protocol was repeated twice. The relative pitch size per player remained constant across the different game formats at around 150 m^2 per player.

3.2.2. Subjects

Ten professional male football players under 19 (age = 18.0 ± 0.67 years, body mass = 69.7 ± 5.66 kg, height = 1.79 ± 0.06 m, body mass index = 21.83 ± 0.98 Kg/m^2, HR_{max} = 193.9 ± 5.0, mean ± SD) participated in this study. All players were members of the same youth team (under 19 years) competing in the Portuguese 1st Division. The team had practice sessions 5 times a week, 90 minutes per session, with an official game during the weekend. Players had a mean of 10.20 ± 1.81 years of experience (minimum of 7 years and maximum of 12 years) and 5 of these players had already represented the National team. Furthermore, all players practiced regularly with the senior professional team that competed in the Portuguese 1st League.

All players and their parents were informed about the research procedures, requirements, benefits and risks, and their written consent was obtained before the study began. The study was approved by the Ethics Committee of the Research Center for Sports Sciences, Health and Human Development, Vila Real, Portugal and by the local ethics committee before the commencement of the assessments. The study protocol followed the guidelines described in the Declaration of Helsinki.

3.2.3. Teams' constitution

The games were played in the last 7 weeks of the competitive season. The coach used subjective evaluation to select the best 10 players and, afterwards, the players were assigned to two teams using specific positions, tactical/technical levels, physical performance and participation in competitive matches (8). The players' tactical/technical level was established according to the subjective evaluation carried out by the coach, who awarded a score of 1 to players with the lowest level and 5 to those with the highest level. The number of minutes played in competitive matches (prior to the beginning of this study) was also used to categorize players; a score of 1 was given to players with the fewest number of minutes played and 5 to those who played the most minutes. Scores on the Yo-Yo intermittent recovery test level 2 (1) were used in the same way: players who covered the least distance were given a score of 1 and those who performed the greatest distance were classified with 5. The total score of each player was the sum of the three scores.

3.2.4. Procedures

Before the first data collection session, a theoretical presentation was given in order to present and discuss the procedures with the participants. Also, an initial session was conducted with a SSG involving all ten participants to familiarize them with the procedures and equipment for data collection. The Yo-Yo intermittent recovery test level 2 (1) was also conducted in this session.

Each SSG format was played twice by the same teams in different sessions. The SSG were played at the beginning of each training session, following a standardized 20-min warm-up, and consisting of running, stretching and a ball possession game. Players played a SSG with 20-minutes duration (3 bouts of 6-minutes with 1-minute of active recovery). After each period of 6-minutes teams changed the attack direction. During the SSG games, formal goals were used and a goalkeeper was added randomly to each team. When the ball was kicked out of play, immediate access to a replacement football was made possible by having a supply of balls placed in the goals and along the boundary line surrounding the entire pitch. Unlimited touches on the ball were allowed and offside rule was not applied during the game. Furthermore, coach encouragement or feedback was not allowed during SSG.

Field dimensions used during different SSG formats were manipulated in order to keep the relative area per athlete constant (19). The ratio was kept in 1:150 m^2 per player.

3.2.5. Rating of Perceived Exertion

Global RPE were recorded immediately after each SSG using the 6-20 Borg scale (2). Standardized instructions for RPE were provided (2). Players were already familiarized with the 6-20 Borg scale before this study.

3.2.6. Heart Rate Monitoring

The HR of each player was recorded at 5 Hz intervals during each SSG via short-range radio telemetry (Polar Team Sports System, Polar Electro Oy, Finland). The HR monitors were also used during the Yo-Yo intermittent recovery test level 2 (1), to determine each player's maximum heart rate (HR_{max}). Exercise intensity during each SSG was assessed using HR, expressed as a percentage of maximum heart rate (% HR_{max}) and classified into four previously defined zones: Zone 1 (<75 % HR_{max}), Zone 2 (75-84 % HR_{max}), Zone 3 (85-90 % HR_{max}), and Zone 4 (>90 % HR_{max}) (19). The HR_{max} reached during Yo-Yo intermittent recovery test level 2 (1) was used as the reference (100 %) value.

3.2.7. Activity profile

Player movements during the SSG were measured using portable global positioning system units, sampled at 5 Hz (SPI-PRO, GPSports, Canberra, ACT, Australia). This equipment operated in non-differential mode and provided data in real time. The GPS is a satellite-based navigation system that enables real time data during training and competition (9, 12, 27, 29). The reliability of the SPI-PRO GPS device for measuring specific movement characteristics in team sports following a known running course was previously examined (9, 14, 27). The authors found that the GPS devices have an acceptable level of accuracy and reliability for total distance and peak speeds during high-intensity and intermittent exercise. The SPI-PRO was placed into a harness that positioned the device between the player's shoulder blades, which was used by each player during all SSG (19). For data analysis purposes, six speed zones were selected (17): speed zone 1 (0–6.9 $Km.h^{-1}$); speed zone 2 (7.0–9.9 $Km.h^{-1}$); speed zone 3 (10.0–12.9 $Km.h^{-1}$); speed zone 4 (13.0–15.9 $Km.h^{-1}$); speed zone 5 (16.0–17.9 $Km.h^{-1}$); and speed zone 6 (sprinting: ≥ 18.0 $Km.h^{-1}$).

3.2.8. Body load

Body load is a modified vector magnitude (3), based on the accelerations detected by the accelerometer from three planes (vertical, horizontal, and anterior-posterior) at 100 Hz. The registered values are internally stored and converted into quantifiable digital signals (39). This variable is expressed, as showed in the following equation, as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (x, y and z) and divided by 100. Data was expressed in arbitrary units. The body load validity has already been established by Boyd *et al*. (3).

$$Body\ load = \frac{\sqrt{(a_{y1}-a_{y-1})^2 + (a_{x1}-a_{x-1})^2 + (a_{z1}-a_{z-1})^2}}{100}$$

Where:

a_y = Forward accelerometer

a_x = Sideways accelerometer

a_z = Vertical accelerometer

The body load results were measured and compared for each minute of SSG play.

3.2.9. Statistical analysis

The data are reported as means ± standard deviations (SD). The HR, % HR_{max}, RPE, distance travelled and total body load were compared across the SSG formats using a one-way analysis of variance (ANOVA). The Bonferroni Post hoc test was used to identify pairwise comparisons. The body load, total distance and distances covered above and bellow $Km.h^{-1}16$ were also analysed per minute by using a repeated measures ANOVA 6x4 (minute: 1, 2, 3, 4, 5, 6 and SSG format: 2-, 3-, 4- and 5-a-side). These results were presented with curves fitted according to the distance-weighted least squares smoothing procedure, i.e., the influence of individual cases decreases with the horizontal distance from the respective cases on the curve. The Bonferroni Post hoc test was used to identify pairwise comparisons. To compare the HR zones and speed zones between SSG formats, the non-parametric Wilcoxon Signed-Rank Test was used with the Bonferroni adjustment. The level of statistical significance was set at $p \leq 0.05$. All statistical analyses were performed using the software IBM SPSS statistics (version 19, SPSS Inc., Chicago, IL, USA).

3.3. RESULTS

3.3.1. Physiological and perceptual characteristics

Table 3.1 presents the time spent in each heart rate zone during the various SSG formats. One-way ANOVA identified statistically significant differences amongst SSG formats in the % HR_{max} ($F = 5.93$; $p = 0.001$). Statistical differences between SSG formats were also found in all times spent in HR zones, except time spent at 75-84 % HR_{max}.

The lowest RPE value was found at the 5-a-side format (13.48 ± 2.67) and the highest value (17.01 ± 2.88) was found at the 3-a-side format. In the 2- and 4-a-side formats the RPE values were 16.83. ± 1.80 and 15.00 ± 2.25, respectively. The one-way ANOVA showed significant differences ($F = 6.08$; $p = 0.001$) between RPE values in the SSG formats. The Bonferroni Post hoc test showed significant differences between the RPE values of 2-a-side *vs.* 5-a-side formats, and between and 3-a-side *vs.* 5-a-side formats.

Table 3.1 – % HR in the different SSG formats (mean ± SD).

SSG Format	2-a-side	3-a-side	4-a-side	5-a-side
% HRmax	87.46±7.46	89.56±3.15[d,e]	85.91±5.98	84.56±7.56
Time below 75 % HR_{max} (31)	0.44±0.50[a]	0.30±0.21[d,e]	0.65±0.84	1.02±1.25
Time at 75-84 % HR_{max} (31)	1.05±0.91	0.68±0.61	1.52±1.09	1.64±1.25
Time at 85-89 % HR_{max} (31)	1.61±1.02[a]	1.52±1.11[d,e]	1.67±1.05[f]	1.27±1.17
Time above 90 % HR_{max} (31)	2.91±1.42[a]	3.50±1.44[e]	2.14±1.78[f]	2.07±1.97

Statistical significant differences are identified as: [a]2-a-side *vs.* 3-a-side; [d]3-a-side *vs.* 4-a-side; [e]3-a-side *vs.* 5-a-side; [f]4-a-side *vs.* 5-a-side.

3.3.2. Activity profile

Table 3.2 presents the total distance covered in each SSG and the distance covered in the six speed zones. Statistically significant differences among SSG formats were found for total distance performed (F = 7.24; p = 0.000). The distance covered in the 2-a-side format was statistically different from all other formats. In the 2-a-side, the players performed the smallest distance in each 6-min period (598.97 ± 78.91 m), while the largest distance was covered in the 3-a-side format (685.71 ± 72.77 m). Considering the distance covered in each speed zone, only the 4- and 5-a side formats did not present statistically significant differences in zone 5 and 6.

The number of sprints (distance performed with a speed ≥ 18 $km.h^{-1}$), performed by players during the four SSG can also be found in table 3.2. Statistically significant differences were found between the number of sprints performed in each SSG (F = 7.82; p = 0.000). The 2-a-side and 3-a-side formats present differences when compared with all other formats. The highest number of sprints was performed in the 3-a-side format (2.50 ± 1.65) and the lowest in the 2-a-side format (0.71 ± 0.86).

Table 3.2 – Activity profile characteristics (mean ± SD) regarding 6 speed zones (m), total distance covered (m), sprints/athlete and body load during all SSG formats.

SSG Format	2-a-side	3-a-side	4-a-side	5-a-side
Zone 1 (0–6.9 $Km.h^{-1}$)	291.84±18.99[a,b,c]	278.44±26.50	272.74±30.62	285.30±26.82
Zone 2 (7.0–9.9 $Km.h^{-1}$)	137.41±34.16[b]	141.14±33.81[d]	163.73±40.36	143.10±37.81
Zone 3 (10.0–12.9 $Km.h^{-1}$)	95.19±38.05[a,b,c]	126.30±38.12	128.38±40.06	117.09±39.31
Zone 4 (13.0–15.9 $Km.h^{-1}$)	48.46±24.68[a,b,c]	79.51±22.37	72.59±24.00	67.40±28.47
Zone 5 (16.0–17.9 $Km.h^{-1}$)	15.58±9.14[a,b]	30.91±11.41	23.61±11.97	25.09±15.23
Zone 6 (≥ 18.0 $Km.h^{-1}$)	10.48±9.92[a,b]	29.42±15.14[e]	21.09±17.23	21.99±16.96
Total distance	598.97±78.91[a,b,c]	685.71±72.77	682.14±76.56	659.98±81.78
Sprints/Athlete	0.71±0.86[a,b,c]	2.50±1.65[d,e]	1.71±1.43	1.74±1.41
Acc load (a.u.)	88.63±20.37	92.32±12.81	95.18±17.54[f]	86.43±14.47
Acc load /min (a.u.)	14.74±3.37	15.33±2.14	15.88±2.93[f]	14.42±2.41

Acc – accumulated; Statistical significant differences are identified as: [a]2-a-side *vs.* 3-a-side; [b]2-a-side *vs.* 4-a-side; [c]2-a-side *vs.* 5-a-side; [d]3-a-side *vs.* 4-a-side; [e]3-a-side *vs.* 5-a-side; [f]4-a-side *vs.* 5-a-side.

Total body load and body load per minute in each SSG format are presented in table 3.2. Statistically significant differences among the SSG formats were found in both variables, (F = 4.03; p = 0.008 and F = 3.83; p = 0.010, respectively). Statistically significant differences between 4- and 5-a-side SSG were found. The 5-a-side format presented the lowest total body load (86.43 ± 14.47), whereas the 4-a-side presented the highest value (95.18 ± 17.54). The same tendency was found in body load per minute, with 14.42 ± 2.41 and 15.88 ± 2.93, respectively. Figure 3.1a presents the body load per minute in each SSG. There was a single effect of minute of play (F = 20.27; p = 0.000) with lower values at the end of each SSG. There were differences in all pairs of minutes with the exception of the following: minute 1 and minute 2, minute 3 and minute 4, minute 5 and minute 6. There was also an interaction with SSG formats (F = 1.73; p = 0.040). There were differences in the following pairs: 2- and 4-a-side, 3- and 5-a-side, 4- and 5-a-side (Figure 3.1a).

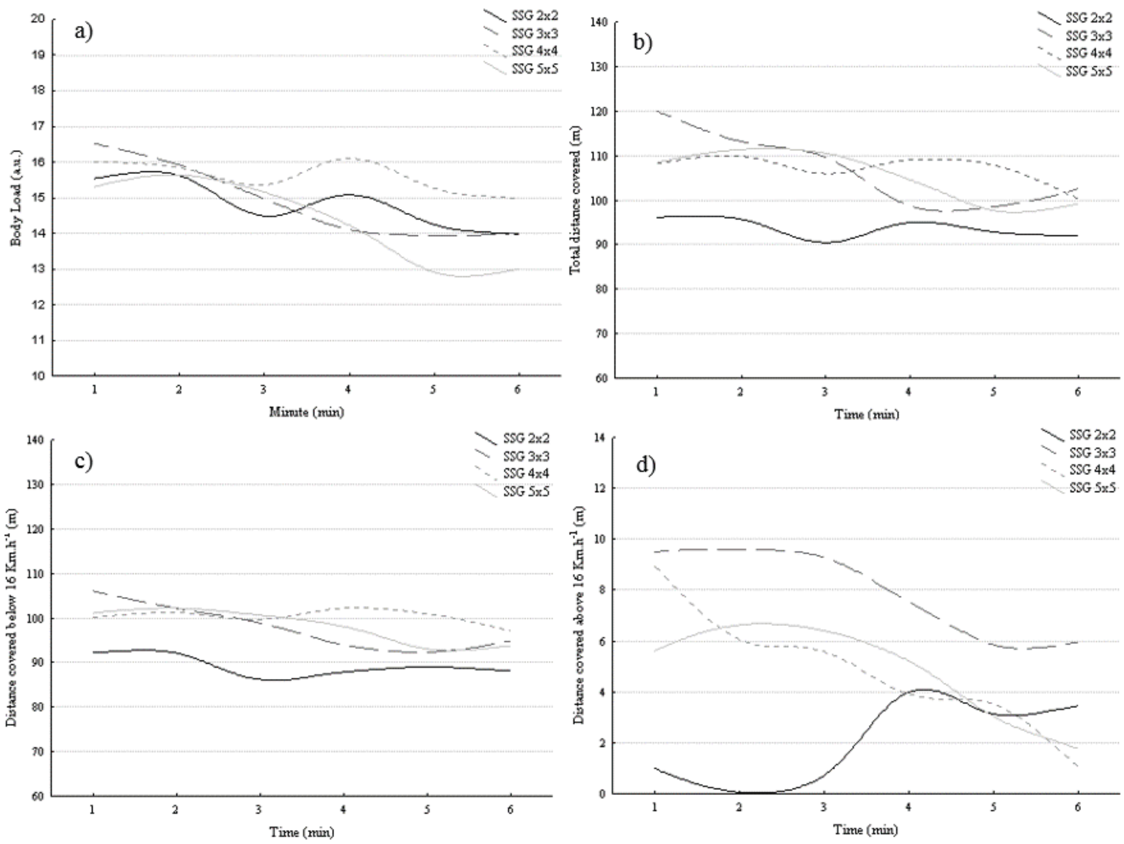

Figure 3.1 - Body load, total distance covered, distance covered below 16 $Km.h^{-1}$ and distance covered above 16 $Km.h^{-1}$ per minute during the four SSG.

Figure 3.1b presents the total distance covered per minute with a significant effect of minute of play (F = 10.8; p = 0.000) and a significant interaction with SSG formats (F = 3.19; p = 0.000). The total distance covered was significantly lower in minutes 5 and 6. Also the 2-a-side game was different from all other formats. These results were similar for the distance covered per minute at lower speeds (F = 9.0; p = 0.000 for minute of play and F = 2.74; p = 0.000 for interaction with SSG formats). Finally, the results for distance covered per minute at higher speeds were not significant either for the effect of minute of play (F = 1.8; p = 0.098) and for the interaction with SSG formats (F = 1.73; p = 0.161, Figure 3.1d).

3.4. DISCUSSION

The aim of this study was to examine the acute physiological responses, activity profile and body load of four football SSG formats (2-, 3-, 4- and 5-a-side) while maintaining the pitch size per player constant. Previous research identified two important aspects not considered in earlier SSG football studies, such as changing the pitch size and the number of players, resulting in several differences in the pitch area per player (10, 13, 23, 24, 33). In the present study, the area:number of players ratio was constant across all SSG formats, with the aim of characterizing HR, perceptual responses, activity profile and body load.

Significant differences were identified in all studied variables. When differences were found, these occurred mainly among the 2- and 3-a-side formats with all the other formats. Monitoring the HR response of players during training is a useful and reliable method for regulating exercise intensity (21, 35). In the present study, the exercise intensity was determined by the HR and % HR_{max}. The results demonstrated that HR values obtained in 3-a-side games were significantly higher than 4- and 5-a-side games. The HR in the 2-a-side game was also significantly higher than in the 5-a-side format. Despite the fact that statistically significant differences between 2-a-side *vs.* 4-a-side and between 4-a side *vs.* 5-a-side games were not found, results, in general, agree with those obtained by several authors (19, 23, 26, 33).

In the present study, the 2- and 3-a-side formats elicited a greater amount of time spent at ≥ 90 % HR_{max} than the 4- and 5-a-side games. Additionally, the HR responses during 5-a-side games were below the mean HR reported during a competitive match (35). Moreover, the players spent less time under previously reported match intensity zones (35), and more time over match intensity in the 2- and 3-a-side format compared with the 4- and 5-a-side formats. The results demonstrated that smaller game formats elicit higher mean HR, and that players spent more time in higher % HR zones. One possible explanation for these results is that an increasing number of players might cause an insufficient involvement, with or without the ball, in the game. Moreover, the presented results suggest that these smaller game formats may be useful in training to improve aerobic fitness in football players, since they can elicit HR responses around 90 % of HR_{max} (21).

Available research suggests that RPE is a valid indicator of high intensity intermittent exercise, when compared with HR and blood lactate concentration during football-specific exercise (11). In the present study, 2- and 3-a-side formats elicited a statistically significant greater RPE-value than the other two formats (4- and 5-a-side). The last format (5-a-side) presented the lowest value (15.00 ± 2.25), while the 2- and 3-a-side formats presented the highest RPE values (17.01 ± 2.88 and 16.83 ± 1.80, respectively). These results are similar to those previously reported (19, 33, 36) and suggest that RPE increases when the number of players decline. In accordance with current research, it appears that an increase in the number of players with constant pitch area per player reduces the player's rating of perceived exertion in football SSG. Another explanation for the reduction in RPE with the increasing number of players may be the decreasing interaction with colleagues and/or opponents (19).

The analysis of the activity profile allows the exercise intensity to approach competition demands (6). The activity profile results showed in this study confirmed the results obtained in the physiological parameters. The total distance performed by players was similar across the three larger formats and significantly smaller in the 2-a-side format. Probably, the smaller distances performed in the 2-a-side format reflect less absolute pitch space to cover during the game.

The highest distance (291.84 ± 18.99 m) performed at low intensity (zone 1 < 7 $Km.h^{-1}$) was found in the 2-a-side format and the smallest distance was found in the 4-a-side format (272.74 ± 26.82 m). These results may be explained by the highest frequency of individual actions during the 2-a-side format, and the lowest absolute space to cover during the 2-a-side game.

In general, the larger game formats were associated with greater ranges of distances traveled at speeds ≥ 18 $Km.h^{-1}$ (10, 19). However, in this study, the 3-a-side format was characterized by significantly longer distances for speeds ≥ 18 $Km.h^{-1}$. The number of sprints (displacements with speed ≥ 18 $Km.h^{-1}$) performed across the SSG formats was significantly lower in the 2-a-side and higher in the 3-a-side format. In the 4-a-side and 5-a-side formats the number of sprints was similar.

The work rates are influenced by the positional role of players and style of play (23, 34). In fact, previous research on football has identified differences between playing formations (4:4:2, 4:3:3 and 4:5:1) particularly for very high-intensity running activity and some technical elements of performance. These differences were particularly noted in attackers (4). In the smaller formats, all players are required to perform defensive and offensive actions. Indeed, the present results indicate that SSG offered a specific training stimulus to simulate the overall movement patterns in competition. However, these training exercises did not simulate the high intensity demands of the competition, since all SSG formats elicit a maximum of approximately 7 % of displacements with high intensity (> 16 $Km.h^{-1}$) compared to a value of 10 % referred to by other authors (34, 35). In agreement with previous literature (19), it is possible that the activity profiles during SSG can be determined by the complex interaction of total pitch area, number of players, opportunity for direct involvement with the ball, and match style. In fact, very recent literature suggests that sprints should be defined as any movement that reaches or exceeds the sprint threshold velocity for at least 1 second and any movement with an acceleration that occurs within the highest 5 % of accelerations found in the corresponding velocity range (15). Using this new definition will probably lead to an increase in the number of sprints recorded during SSG.

The football players' game workload is intermittent, maximal and aerobic based, with 1000 to 1350 changes in activity during the 90 minutes, which means a change of activity every 4-6 seconds (30). The recorded accelerations or decelerations give a description of the frequency, time and intensity of the physical activity produced by body movement (37). The accumulated body load increased with the number of players until the 4-a-side; however, in the 5-a-side results, a significant decrease to lower values than 2-a-side format was verified. A possible explanation for the highest body load found in the 4-a-side game could be the complex interactions with a wider pitch area, three teammates and four opponent players and still having very frequent opportunities for direct involvement with the ball. Moreover, the 4-a-side is the format with the lower number of players where all defensive (delay, concentration, balance, and control/restraint) and offensive (penetration, width, mobility, and improvisation) principles of the game can be found (38). On the other hand, the 5-a-side game is the first SSG to present a game organization where the players are required to assume specific playing positions, otherwise the team will not be able to cover all the pitch adequately. Therefore, this playing strategy implies a decrease in direct involvement with the ball and, consequently, a decrease in body load.

The accumulated load per minute values are very similar to those obtained by Casamichana *et al.* (7) during SSG (15.8 ± 2.7) and were higher to those obtained in friendly matches (13.5 ± 1.5). These results suggest that SSG are played at a higher intensity than friendly matches. Contrarily, Montgomery and co-workers (31) found results that suggest that body load was greater during basketball game play than during practice drills. The same authors found body load per minute values in defensive and offensive drills similar to those we found in the SSG formats. One interesting novelty in this study was the fact that body load values decreased each 2 minutes of game play along with decreases in total distance and distance below 16 $Km.h^{-1}$ only after four minutes of play. Nevertheless, no statistically differences were found in the distance performed above 16 $Km.h^{-1}$, probably due to the variability and unpredictability of the game. Therefore, these results suggest that after 2 minutes of play (0-2 min) the accelerations/decelerations are impaired, however, with no consequences yet for distance covered at lower speeds. In the following 2 min (2-4 min) there was additional impairment in accelerations/decelerations but now with less distance covered at lower speeds. The last 2 min (4-6 min) showed lower accelerations/decelerations with no consequences for distance covered at lower speeds. These results may suggest that SSG duration can be programmed in 2 min blocks interspersed with very short periods of rest, in order to allow for a quick recovery and maintenance of the workload characteristics. These concerns are particularly important when using 5-a-side games because at the end of the game period the body load has substantially decreased.

3.5. PRATICAL APPLICATIONS

The results of our study showed that physiological and perceptual responses are higher in the smaller SSG formats. Additionally, results suggest that smaller game formats may be useful for training to improve aerobic fitness in football players, since they can elicit HR responses around 90 % of HR_{max}. This could indicate that smaller formats are more appropriate to increase physiological stress, while larger formats can be used to improve match-specific demands. This information is useful for coaches, since they can modify or introduce rules in the SSG formats to adjust them to the competition demands. The body load was influenced by the SSG format with the results suggesting that coaches can manipulate the duration of play in 2 min periods. While maintaining a constant area:player ratio, coaches can use lower number of players (2- and 3-a-side) to increase cardiovascular demands, but higher number of players (4- and 5-a-side) to increase variability and specificity. Activity profile and body load were not as different as expected, however, 4-a-side SSG presented higher values and higher variability and, again, the 3-a-side SSG was the most stable format.

3.6. REFERENCES

1. Bangsbo J, Iaia FM, and Krustrup P. The Yo-Yo intermittent recovery test - A useful tool for evaluation of physical performance in intermittent sports. *Sports Med* 38: 37-51, 2008.
2. Borg G. *Borg's Perceived Exertion and Pain Scales*. Champaign, Ill: Human Kinetics., 1998.
3. Boyd LJ, Ball K, and Aughey RJ. The Reliability of MinimaxX Accelerometers for Measuring Physical Activity in Australian Football. *Intj Sport Physiol* 6: 311-321, 2011.
4. Bradley PS, Carling C, Archer D, Roberts J, Dodds A, Di Mascio M, Paul D, Diaz AG, Peart D, and Krustrup P. The effect of playing formation on high-intensity running and technical profiles in English FA Premier League soccer matches. *J Sport Sci* 29: 821-830, 2011.
5. Carling C, Bloomfield J, Nelsen L, and Reilly T. The Role of Motion Analysis in Elite Soccer Contemporary Performance Measurement Techniques and Work Rate Data. *Sports Med* 38: 839-862, 2008.
6. Carling C, Williams AM, and Reilly T. *Handbook of soccer analysis*. Oxon, RN: Routledge, 2005.
7. Casamichana D, Castellano J, and Castagna C. Comparing the Physical Demands of Friendly Matches and Small-Sided Games in Semiprofessional Soccer Players. *J Strength Cond Res* 26: 837-843, 2012.
8. Castellano J and Casamichana D. Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *J Sport Sci* 28: 1615-1623, 2010.
9. Coutts AJ and Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 13: 133-135, 2010.
10. Coutts AJ, Hill-Haas SV, Dawson B, and Impellizzeri FM. Physiology of small-sided games training in Football a systematic review. *Sports Med* 41: 199-220, 2011.
11. Coutts AJ, Rampinini E, Marcora SM, Castagna C, and Impellizzeri FM. Heart rate and blood lactate correlates of perceived exertion during small-sided soccer games. *J Sci Med Sport* 12: 79-84, 2009.
12. Cunniffe B, Proctor W, Baker JS, and Davies B. An evaluation of the physiological demands of elite Rugby Union using global positioning system tracking software. *J Strength Cond Res* 23: 1195-1203, 2009.
13. Dellal A, Chamari K, Pintus A, Girard O, Cotte T, and Keller D. Heart rate responses during small-sided games and short intermittent running training in elite Soccer players: A comparative study. *J Strength Cond Res* 22: 1449-1457, 2008.
14. Duffield R, Reid M, Baker J, and Spratford W. Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports. *J Sci Med Sport* 13: 523-525, 2010.
15. Dwyer DB and Gabbett TJ. Global positioning system data analysis: velocity ranges and a new definition of sprinting for field sport athletes. *J Strength Cond Res* 0: 1-7, 2012.
16. Gabbett TJ and Mulvey MJ. Time-motion analysis of small-sided training games and competition in elite women Soccer players. *J Strength Cond Res* 22: 543-552, 2008.
17. Hill-Haas S, Coutts A, Rowsell G, and Dawson B. Variability of acute physiological responses and performance profiles of youth soccer players in small-sided games. *J Sci Med Sport* 11: 487-490, 2008.
18. Hill-Haas SV, Coutts AJ, Dawson BT, and Rowsell GJ. Time-motion characteristics and physiological responses of small-sided games in elite youth players: The influence of player number and rule changes. *J Strength Cond Res* 24: 2149-2156, 2010.

19. Hill-Haas SV, Dawson BT, Coutts AJ, and Rowsell GJ. Physiological responses and time-motion characteristics of various small-sided soccer games in youth players. *J Sport Sci* 27: 1-8, 2009.

20. Hill-Haas SV, Rowsell GJ, Dawson BT, and Coutts AJ. Acute physiological responses and time-motion characteristics of two small-sided training regimes in youth Soccer players. *J Strength Cond Res* 23: 111-115, 2009.

21. Hoff J, Wisloff U, Engen LC, Kemi OJ, and Helgerud J. Soccer specific aerobic endurance training. *Brit J Sport Med* 36: 218-221, 2002.

22. Jennings D, Cormack S, Coutts AJ, Boyd LJ, and Aughey RJ. Variability of GPS Units for Measuring Distance in Team Sport Movements. *Intj Sport Physiol* 5: 565-569, 2010.

23. Jones S and Drust B. Physiological and technical demands of 4 v 4 and 8 v 8 games in elite youth soccer players. *Kinesiology* 39: 150-156, 2007.

24. Kellis E and Katis A. Effects of small-sided games on physical conditioning and performance in young soccer players. *J Sport Sci Med* 8: 374-380, 2009.

25. Koklu Y, Asci A, Kocak FU, Alemdaroglu U, and Dundar U. Comparison of the physiological responses to different small-sided games in elite young Soccer players. *J Strength Cond Res* 25: 1522-1528, 2011.

26. Little T and Williams AG. Suitability of soccer training drills for endurance training. *J Strength Cond Res* 20: 316-319, 2006.

27. MacLeod H, Morris J, Nevill A, and Sunderland C. The validity of a non-differential global positioning system for assessing player movement patterns in field hockey. *J Sport Sci* 27: 121-128, 2009.

28. Mallo J and Navarro E. Physcial load imposed on soccer players during small-sided training games. *J Sport Med Phys Fit* 48: 166-171, 2008.

29. McLellan CP, Lovell DI, and Gass GC. Biochemical and endocrine responses to impact and collision during elite Rugby League match play. *J Strength Cond Res* 25: 1553-1562, 2011.

30. Mohr M, Krustrup P, and Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519-528, 2003.

31. Montgomery PG, Pyne DB, and Minahan CL. The Physical and Physiological Demands of Basketball Training and Competition. *Intj Sport Physiol* 5: 75-86, 2010.

32. Petersen C, Pyne D, Portus M, and Dawson B. Validity and reliability of GPS units to monitor Cricket-specific movement patterns. *Intj Sport Physiol* 4: 381-393, 2009.

33. Rampinini E, Impellizzeri FM, Castagna C, Abt G, Chamari K, Sassi A, and Marcora SM. Factors influencing physiological responses to small-sided soccer games. *J Sport Sci* 25: 659-666, 2007.

34. Reilly T. Motion analysis and physiological demands, in: *Science and Soccer*. T Reilly, ed. London: E & FN Spon, 1996.

35. Reilly T. *The science of training - Soccer: A scientific aproach to developing strength, speed and endurance.* London: Routledge, 2007.

36. Sampaio J, Garcia G, Maças V, Ibanez J, Abrantes C, and Caixinha P. Heart rate and perceptual responses to 2 x 2 and 3 x 3 small-sided youth soccer games. *J Sport Sci Med* 6: 2, 2007.

37. Vanhelst J, Theunynck D, Gottrand F, and Beghin L. Reliability of the RT3 accelerometer for measurement of physical activity in adolescents. *J Sport Sci* 28: 375-379, 2010.

38. Wade A. *Principles of Team Play.* Spring City PA: Reedswain Inc, 1996.

39. Wickel EE, Welk GJ, and Eisenmann JC. Concurrent validation of the bouchard diary with an accelerometry-based monitor. *Med Sci Sport Exer* 38: 373-379, 2006.

CHAPTER 4

TACTICAL BEHAVIOUR DURING FOUR SMALL-SIDED GAMES IN FOOTBALL

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ABSTRACT

The aim of this study was to describe tactical behaviour in small-sided games (SSG) in football using positional data. Ten professional players participated in 2-, 3-, 4- and 5-a-side SSG, played in 3 bouts of 6 min. with 1 min. of passive rest between bouts. Positional data were collected using portable global positioning system units (5Hz) and used to calculate: distance between players to both own and opponent team centroids; distance between centroids; angle between two players and the own centroid. Approximate entropy was used to identify the time series regularity. The distance to own team centroid increased with the number of players ($p<0.001$). The results from the distance to the opponent's centroid exhibited a similar trend, with higher values ($p<0.001$). The distance between centroids decreased from 2- to the 4-a-side, but then increased in 5-a-side. A higher number of players was associated to higher regularity, suggesting higher positional organization in SSG with more players. A direct relationship between the angles performed by players' dyads with the own team centroid was found, suggesting the existence of different relationships between players. The highest regularity found in 4- and 5-a-side identified these formats as more adequate to promote emergent and self-organized behaviours.

Key Words: Complex systems; Dynamical systems; GPS

Submited

4.1. INTRODUCTION

Performance in team sports is the result of a long-term training process designed to prepare the players for the complex requirements of competition (Duclos et al. 2008; Sampaio & Maçãs 2012), with special emphasis on self-organizing properties and dynamic adaptive behaviour to environmental constraints (Bourbousson et al. 2010b; Dellal et al. 2008; Lames & McGarry 2007; Sampaio & Maçãs 2012). In fact, a systematic view of team sports may be seen as fundamental to the emergence of a new understanding of games (Grehaigne et al. 2011). One of the major challenges of this approach is the possibility to investigate interactions between players, both within and between teams, with the goal to identify patterns of play (McGarry et al. 2002). This approach also allows describing the formation of emergent game patterns (Vilar et al. 2012), but tries to preserve the sequential and situational character of game events.

The available literature presents interesting frameworks about this topic, for example, describing the game of football as a game sport including subsystems with intra- and inter-dynamic interactions (Lames & McGarry 2007). Thus, the dynamical structure of team sports could be investigated at different levels, from individual (Bourbousson et al. 2010a; Travassos et al. 2011) to collective interactions (Bourbousson et al. 2010b; Frencken et al. 2012; Frencken & Lemmink 2008; Frencken et al. 2011; Sampaio & Maçãs 2012; Travassos et al. 2012).

Bourbousson et al. (2010a) examined space-time patterns of basketball players during a game by evaluating all playing dyads. The authors found strong in-phase correlations between player dyads in longitudinal and lateral directions. In another study focusing on futsal players' dyads different coordination dynamics for the defending and attacking dyads was found (Travassos et al. 2011). This suggests that team objectives at each moment (attack or defence) are reflected in an overarching game structure. Searching for a collective variable that captures the dynamics of team sports Frencken et al. (2011) studied the centroid position and the surface area of two teams during a 4-a-side SSG. The authors found a strong linear relation between the forward-backward motion of the centroids. They concluded that surface area and particularly centroid position might be collective variables that capture the team dynamics. In another study the teams centroid position longitudinally and laterally was analysed during an international-standard football match (Frencken et al. 2012). The authors found that periods of high variability in inter-team distances were linked with collective defensive actions and team reorganisation in dead-ball moments rather than goal attempts. Folgado et al. (2012) tried to measure teams tactical performance in 3- and 4-a-sided SSG performed by youth football players using a new variable, the length per width ratio (*lpwratio*). They found that younger teams presented higher *lpwratio* and concluded that this variable could be a useful tool to measure tactical performance in youth football SSG.

From this perspective, player positioning can be a candidate for understanding tactical performance in football (Duffield et al. 2010; Kannekens et al. 2011) in a way to capture collective decision making and players' coordination within the team principles of the game (Sampaio & Maçãs 2012). In this way, it is assumed that tactical performance in football depends upon how players are dynamically positioned according to the teams' overall space distribution and the dynamic functional constrains at the scale of the environment (Araujo et al. 2006).

The currently available studies are mostly descriptive and focused on collective variables in discrete 1-a-side match game situations, disregarding, for example, the importance of small-sided games (SSG) as football tactical training drills. In fact, SSG are considered representative training forms for improving fitness, technical and decision-making skills (Brito et al. 2012; Coutts et al. 2011; McGarry et al. 2002). In addition, they represent coherent sub-phases of full-sized football matches (Davids et al. 2007), and the game flow can be described by using variables such as the centroid position or the surface area of a team (Frencken & Lemmink 2008). Although research focused on SSG is scarce, it suggests that team centroids tend to move in the same direction over the course of a SSG game especially in forward-backward direction (Frencken & Lemmink 2008). A more recent study showed that positional data can be used to monitor players' expertise during SSG and, therefore, can be important performance indicators (Sampaio & Maçãs 2012). A further advance in research would be to identify the effects from the number of players on tactical behaviour during the SSG. In fact, describing high-level players positional behaviour when playing 2-, 3-, 4- and 5-a-side SSG would help to better understand game dynamics and players adaptive responses to these changes in teams' configurations.

4.2. Materials and methods

4.2.1. Participants

Ten under 19 male professional football players (age = 18.0 ± 0.6 years, mean ± SD), with on average 10.2 ± 1.8 years of experience (range between 7 and 12 years) participated in this study. In order to control for variability in team-related tactical responses, all players were members from the same team competing in the Portuguese 1st Division (practice sessions 5 times a week – total of 450 minutes - and one official game during the weekend). Five of these players represented the Portuguese National team. Furthermore, all players practice regularly with the elite professional team that competed in the Portuguese 1st League and in the Europa League.

All players, parents or legal guardians, and team supervisors were informed about the research procedures, requirements, benefits and risks, and signed a written consent before the start. The study followed the guidelines from the Declaration of Helsinki and was approved by the Ethics Committee of the Research Centre for Sports Sciences, Health and Human Development, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal.

4.2.2. Teams' constitution

The SSG were played in the last eight weeks of the competitive season 2011-2012. The coach selected the best 10 players based on their tactical skills. Thereafter, he divided the players in two outbalanced teams using playing positions, tactical/technical levels, physical capacities and participation in competitive matches, as suggested by recent literature (Hughes & Bartlett 2002; Nevill et al. 2002).

4.2.3. Experimental design

Before the first data collection session, a brief oral presentation was given in order to explain the procedures to the players. Next, a practice session was conducted with one SSG to familiarize the players with the procedures and equipment for data collection.

The protocol consisted of four SSG formats with 2-, 3-, 4- and 5-a-side players. Each game format was played twice by the same teams in different sessions with a week interval during 8 consecutive weeks. SSG were played at the beginning of each training session, following a standardized 20-min warming-up consisting of running, stretching and a ball possession game with moderate intensity. Players performed SSG with 20-minutes duration (3 bouts of 6-minutes with 1-minute of active recovery in between). After each period of 6-minutes the teams changed the playing direction. SSG were played with formal goals with randomly assigned goalkeepers per game. When the ball was kicked outside of the pitch, the corresponding goalkeeper made the replacement as fast as possible, using extra balls placed in the goals. The offside rule was not applied during the game and coach encouragement or feedback was not allowed. The area for each player was kept to $150m^2$ (Hughes & Bartlett 2002; Nevill et al. 2002). Pitch dimensions can be found in table 1.

4.2.4. Measurements

Positional data was gathered using portable 5 Hz global positioning system units (SPI-PRO, GPSports, Canberra, ACT, Australia). The accuracy of the SPI PRO is ~1-5% based on the manufacturer's information (GPSports 2008) and independent verifications of reliability and validity were satisfactory, when established against criterion measures of speed and distance (Coutts & Duffield 2010; Norton & Edgecomb 2006).

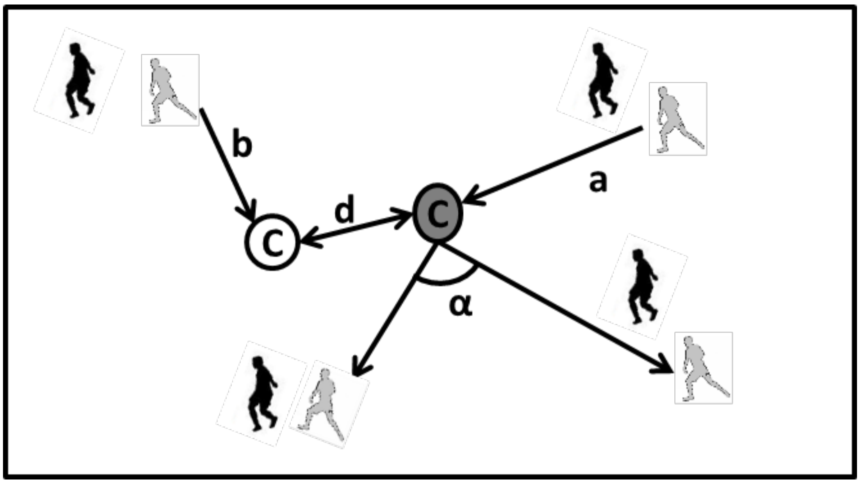

Figure 4.1 – Representation of the variables: a) distance to own team centroid; b) distance to opponent team centroid; C) team centroid; d) distance between centroids; α) angle between players and centroid.

Positional data (x, y) allowed calculating the following variables (Figure 4.1): (i) team centroid - C, this variable provides the mean position of all team players, with exception of the goalkeeper; (ii) distance to centroid – a, this variable provides the absolute distance of each player to the geometric centre of the team, plotted against time; (iii) distance to opponents centroid – b, this variable provides the absolute distance of each player from the geometric centre of the opposite team, plotted against time; (iv) Distance between teams' centroids – d; this variable provides the absolute distance between the geometric centres of the two teams, plotted against time; and, (v) Angle between dyads of players with centroid – α, considering any "ABC" triangle, with opposite sides of the internal angles $\hat{A}\hat{B}\hat{C}$ and known "abc" measures were "a" represents the distance between player "n1" and the team centroid, "b" represents the distance between player "n2" and the team centroid and "c" represents the distance between player "n1" and player "n2". Using the law of cosines (Buddenhagen et al. 1992) the angle performed by players "n1" and "n2" with the team centroid was calculated (Figure 4.1 – angle α). In order to control inter-player variability, this variable was calculated for the three dyads of players that participated in the 3-a-side SSG and was compared with these same dyads in 4- and 5-a-side SSG.

4.2.5. Data processing and analysis

The data recorded by GPS (x and y coordinates) were exported to MATLAB (version 6.5; The Mathworks Inc., Natick, MA) for processing and analysis. Approximate Entropy (ApEn) was calculated to identify the regularity in player's movement patterns. According to previous literature (Pincus 1991; Pincus & Goldberger 1994; Preatoni et al. 2010), ApEn value is an adequate statistical procedure to analyse non-linear time series data that holds both deterministic chaotic and stochastic process. The ApEn algorithm quantifies regularity in a time series, by measuring the logarithmic likelihood that runs from patterns that are close (within r) to "m" contiguous observations and remain close (with the same tolerance wide r) on subsequent incremental comparisons (Duclos et al. 2008; Pincus 1991; Pincus & Goldberger 1994). Input values of vector length (m) was 2.0 and the tolerance factor (r) was 0.2 standard deviations (Stergiou et al. 2004). The obtained values are unit-less real numbers ranging from 0 to 2, with lower values corresponding to more repeatable sequences of data points (Pincus 1991). In this particular case, the ApEn values will allow quantifying and comparing the amount of regularity in players' positional data, when playing the different SSG formats.

The data are reported as means ± standard deviations. A one-way analysis of variance (ANOVA) was performed to identify differences in positional variables across the SSG formats. When appropriate, a Bonferroni Post Hoc test was applied to assess pairwise comparisons. In addition, each bout was independently fitted in a linear trend line. The angles between players' and centroid were fitted in polynomial trend lines, using the distance-weighted least squares smoothing procedure, i.e., the influence of individual cases decreases with the horizontal distance from the respective cases on the curve.

The level of statistical significance was set at $p \leq 0.05$. All statistical analyses were performed using the software IBM SPSS statistics (version 20, SPSS Inc., Chicago, IL, USA).

4.3. RESULTS

The absolute distance to the team centroid increased significantly with the players' number. Results also identified a very small variability among the three bouts within a SSG session, as seen by the almost overlapping trend lines (see table 4.1 and figure 4.2). Within each SSG format, the different players presented high stability in the distance to the team centroid as revealed by the trend lines fitting R^2 values (figure 4.2). Additionally, the ApEn values suggested that in the SSG formats with more players, distance to team centroid was more predictable than in the formats with less players (figure 4.2).

Table 4.1 – Descriptive and comparative results from positioning variables across the SSG formats. Results are mean ± standard deviation.

SSG		2x2	3x3	4x4	5x5	F	*p*	η^2
field dimensions		28x21m	35x26m	40x30m	44x34m			
Team Centroid								
Distance (m)	Bout 1	3.93±0.27^{a}	5.63±0.62^{b}	6.40±0.84^{b}	8.03±1.32^{c}	38.72	*	0.70
	Bout 2	4.39±0.34^{a}	5.72±0.68^{b}	6.72±0.61^{c}	7.64±1.34^{d}	26.62	*	0.61
	Bout 3	4.48±0.41^{a}	5.75±0.65^{a,b}	6.74±0.78^{b,c}	7.71±1.58^{c}	19.15	*	0.53
ApEn	Bout 1	0.26±0.03^{a}	0.25±0.04^{a,b}	0.20±0.19^{b}	0.17±0.03^{c}	26.88	*	0.61
	Bout 2	0.25±0.03^{a}	0.23±0.03^{a,b}	0.22±0.04^{b}	0.17±0.02^{c}	26.08	*	0.61
	Bout 3	0.22±0.04^{a}	0.22±0.03^{a}	0.21±0.03^{a}	0.16±0.04^{b}	17.45	*	0.51
Opponent Team Centroid								
Distance (m)	Bout 1	5.34±0.79^{a}	6.64±0.69^{a}	7.03±1.40^{a}	10.06±2.59^{b}	18.42	*	0.52
	Bout 2	5.68±0.64^{a}	6.85±0.78^{a}	7.41±1.23^{a}	9.73±2.34^{b}	15.70	*	0.48
	Bout 3	5.83±103^{a}	6.71±0.66^{a}	7.41±1.59^{a}	9.36±2.22^{b}	11.60	*	0.41
ApEn	Bout 1	0.30±0.02^{a}	0.27±0.03^{a}	0.23±0.02^{b}	0.15±0.03^{c}	70.13	*	0.80
	Bout 2	0.27±0.03^{a}	0.24±0.02^{a,b}	0.22±0.06^{b}	0.17±0.03^{c}	35.71	*	0.68
	Bout 3	0.25±0.04^{a}	0.25±0.03^{a}	0.21±0.02^{b}	0.16±0.03^{c}	33.61	*	0.67
Centroid to centroid								
Distance (m)	Bout 1 (ApEn)	3.61±1.64^{a} (0.23)	3.51±1.69^{a} (0.21)	3.16±1.50^{b} (0.17)	5.73±2.71^{c} (0.16)	1519.64	*	0.20
	Bout 2 (ApEn)	3.59±20.3^{a} (0.23)	3.70±2.14^{a} (0.20)	3.28±1.70^{b} (0.20)	5.29±2.70^{c} (0.16)	776.78	*	0.08
	Bout 3 (ApEn)	3.70±2.16^{a} (0.22)	3.49±1.71^{b} (0.20)	3.30±1.62^{c} (0.17)	4.70±2.16^{d} (0.15)	434.54	*	0.09

The average values followed by the same letter, in the same line, are not significantly different between them ($p > 0.05$). * denotes significant differences $p<0.001$.

The absolute distance to the opponent team centroid was higher than the absolute distance to own team centroid (table 4.1) and increased with the players' number (figure 4.2). There were significant differences between the 5-a-side format and all other formats in the three bouts (table 4.1). Within each SSG format, the players presented high stability of distances to the team centroid as revealed by the R^2 values obtained in trend lines (figure 4.2). The ApEn values found for the absolute distance to opponent team centroid suggested that this distance is less predictable in SSG formats with less players

Figure 4.3 presents the distance between team centroids for the 3 bouts across the SSG formats. The distance between centroids decreased from 2- to 4-a-side and increased to the highest distance in 5-a-side SSG. There were significant differences between SSG in each of the bouts (table 4.1). The distance between centroids presented higher stability between bouts, as seen by the overlapping trend lines. The ApEn values for the distance between centroids decreased with the increase of the number of players.

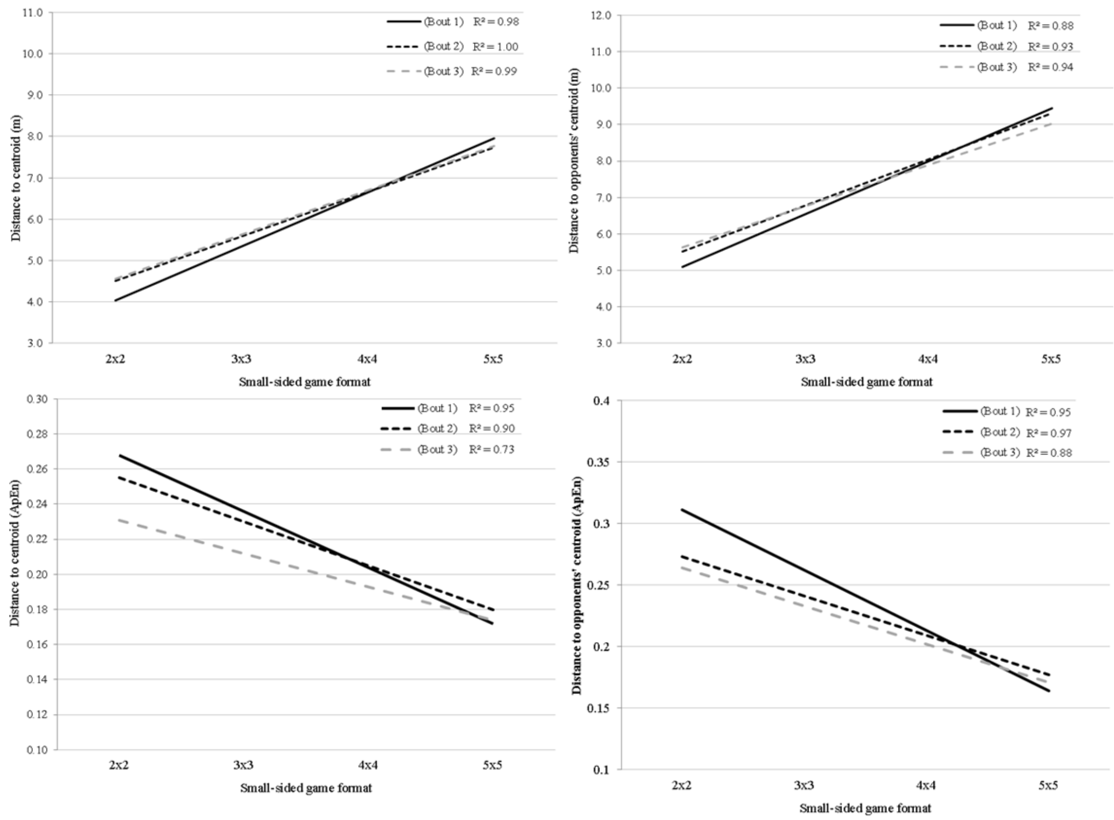

Figure 4.2 – Absolute distance (m) from each player to both team and opponent team centroid in bout 1, 2, 3 and respective ApEn.

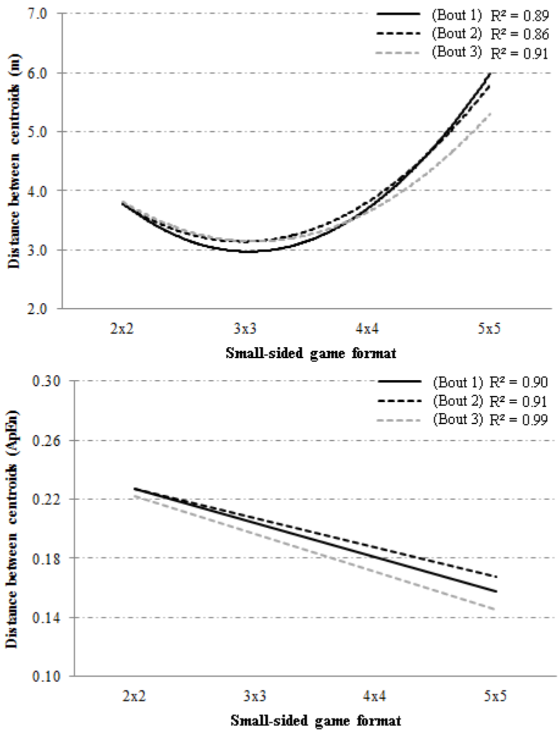

Figure 4.3 – Absolute distance (m) between team centroids and respective ApEn.

Figure 4.4 presents the angle between the players' dyads and the team centroid (4.4a: 1 and 2, 4.4b: 1 and 3, 4.4c: 2 and 3) and the regularity of these angles across 3, 4- and 5-a-side SSG (figure 4.4d). In 3-a-side, frequencies between 0-30 degrees were very scarce. In this SSG format there were higher accumulated frequencies between 120 and 150 degrees. In 5-a-side there was a more homogenous angle distribution between 0º and 180º. The polynomial trend lines showed a lower adjustment in the 5-a-side, compared with the other SSG. For all dyads, the ApEn values were very similar and revealed lower regularity in 3-a-side and higher regularity in 5-a-side SSG (figure 4.4d).

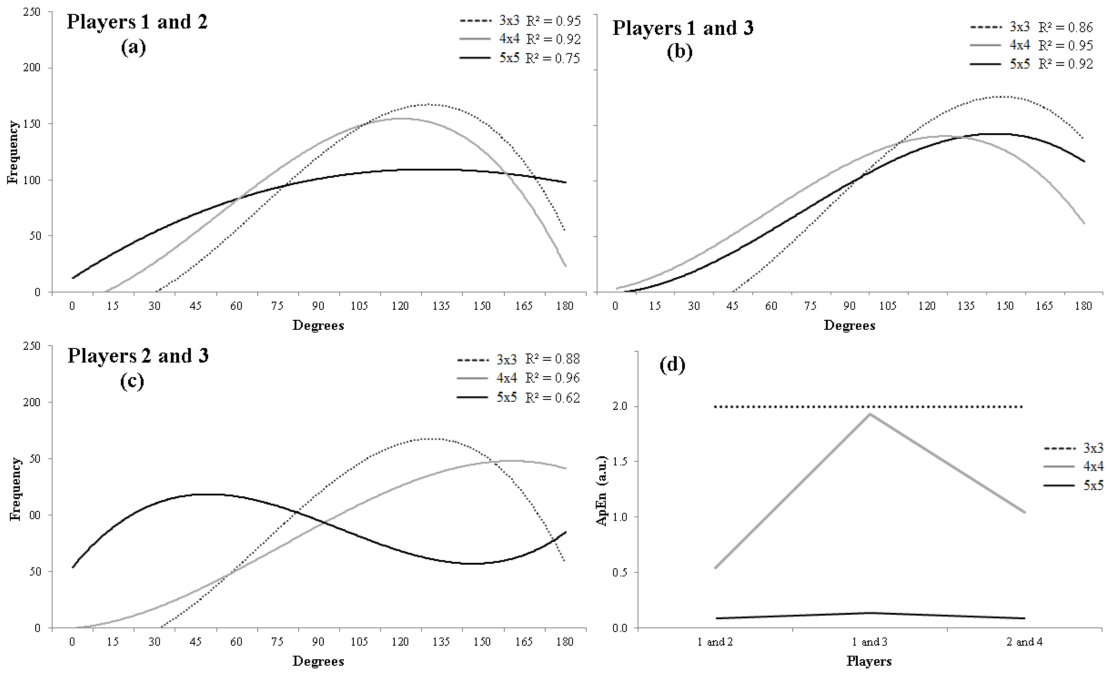

Figure 4.4 – Angle performed between the players' dyads (a: 1 and 2, b: 1 and 3, c: 2 and 3) using the team centroid as reference across the 3-, 4- and 5-a-side SSG. The variation of ApEn in these dyads is presented in panel d.

4.4. DISCUSSION

The football players' positional data were used to access tactical positioning, using variables such as players' distance to team centroid, distance between team's centroids, and relationship between players using the angle performed between players' dyads and team centroid. The absolute distance from the players to both team and opponents' team centroid increased from 2-a-side to 5-a-side SSG formats, but the regularity increase across the SSG formats. These results suggest that training tactical performance requires using a higher number of players. According to Frencken and co-workers (2012) task constrains can influence the functional interpersonal distances between them. This in turn affects the dynamic inter-player coordination that influences the decision-making process (Davids et al. 2005). During the game, players continuously search for stable attractors, e.g. team centroid, that best represent collaborative work and inter-players coordination during the game (Davids et al. 2006; Vilar et al. 2012). The current results suggest that lower inter-player distance in SSG formats with less players, require additional short-distance movements, which probably leads to a decrease in regularity. As the number of players increases, there is higher regularity, probably because larger inter-player distances allow increasing decision time and, thus, allowing the players to perceive more information. Therefore, the centroid seems a strong dynamical attractor, once the players are aware of the information sources that specify goal achievement and the selected option can be an opportunity for action (Duarte et al. 2012b; Frencken et al. 2012; Sampaio & Maçãs 2012). In essence, the low variability in players distance to team centroid suggests a higher commitment with team strategy and a higher coordination between players. The high-level of expertise of the players can be an additional explanation to this fact, because an enhanced collective approach to the game can lead to a more balanced pitch distribution. This finding is in accordance with previous research (Frencken et al. 2011; Lames et al. 2010) concluding that team centroids moves in the same direction over the course of game and is influenced by the ball position. Concomitantly, it might be hypothesised that players further away from the team centroid probably had a lower chance to receive a pass from a teammate since the execution is more difficult and also because his teammate had a lower probability of seeing him. Therefore, by knowing and understanding the absolute distance between players, coaches may plan and monitor the training drills more accurately. For example, distance to team centroid could indicate what kind of pass players should perform during the training session to improve their performance. Also, SSG with less number of players could be an optimal task to achieve higher levels of unpredictability. Previous research has demonstrated that lower level of regularity in a 1-a-side situation was a key feature related to successful attacking performance (Duarte et al. 2012a).

Results in the current study are very similar between the three bouts, most likely as a result of the high level of expertise of the participating players (more than ten years of experience). In fact, playing football at this level requires sharing positioning and principles of play (Kannekens et al. 2011), that are key to develop inter-player coordination and, consequently, to develop organized and effective team play. In contrast to our findings Folgado et al. (2012) found higher distances to team centroid in 3-a-side compared to 4-a-side SSG in amateur under-13 players, suggesting an effect of level of expertise.

The absolute distance from players to the opponents' centroid was higher than to their own team centroid. However, the tendency of increased distances with the increase of the number of players remained. The ApEn values were higher compared to those obtained for the distance to own team centroid. It was already suggested that dynamic inter-players' coordination tendencies in relation to the opponent team should present a higher level of irregularity in order to be unpredictable in attacking situations (Duarte et al. 2012a). Concomitantly, the increase of absolute distance in relation to the opponent team centroid suggests that players react to the opponents' movements, in respect to the general rules of the game, searching for advantage in specific moments during the game.

The absolute distances were higher in SSG formats with more players. This can be explained by the positioning principles of play that regulate team offensive and defensive organizations during the game. In the SSG formats with less players, the participants need to move continuously with the aim to support teammates in order to create opportunities to pass the ball. However, the SSG formats with more players require the players to perform differently, because they need to develop their activity in a larger area, their roles are more specific and they are not always involved in near-the-ball actions (Ouellette 2004; Wade 1996).

The ball position plays a crucial role for the inter-team distance (Dellal et al. 2008). In this study, the distance between centroids was lower in 4-a-side, but higher and less random in 5-a-side. The 4-a-side SSG is the minimal format where all defensive (delay, concentration, balance, and control/restraint) and offensive (penetration, width, mobility, and improvisation) principles of the game are incorporated (Wade 1996). Therefore, a lower distance between centroids can be the result of higher inter-team coordination. Accordingly, the 5-a-side game is the only format that represents an organization with specific playing positions; otherwise the team will not be able to cover the whole. The higher regularity values in this SSG format confirm that positioning on the pitch is the result of intra and inter-team coordination.

The angles between dyads and team centroid can be a candidate to provide information about team structure and the players' commitment with the team structure. The variability found in the players' dyads across the SSG formats suggested different relationships between players across these formats. These results also suggested a preferred mode of communication in the 3-a-side game, as seen by the higher frequencies of angles between 100º and 150º. These frequencies decreased with the increase in the number of players. However, ApEn values showed higher regularity in the 5-a-side format, probably explained by the constant movement of players in the lower formats to support their teammates and create imbalances in the opponent organization. This was supported an earlier study of Aguiar and co-workers (2013), who found higher distances, higher speeds and higher number of sprints of players in SSG formats with less players. Despite the presence of the same goals in the SSG formats with more players, the players seem to use a higher level of organization and a more rational space occupation that in turn leads to a more stable behaviour of the players in these SSG formats.

4.5. PERSPECTIVE

This study provided evidence on how the positioning variables across different football SSG formats can be a strong candidate to describe the players and teams' tactical behaviour. This is the first report showing the emergent behavioral dynamics when changing the number of players. These results reveal new insights for human movement scientists, as they introduce new variables contributing to an explanation of perception-action cycles. Also of interest is the possibility of identifying the interactions between these tactical-related variables with their physiological requirements, towards reaching a holistic, and consequently accurate, understanding of these sports.

4.6. References

Aguiar M, Botelho G, Gonçalves B, Sampaio J. Physiological responses and activity profiles of football small-sided games. J Strength Cond Res 2013: 27: 1287-1294.

Araujo D, Davids K, Hristovski R. The ecological dynamics of decision making in sport. Psychol Sport Exerc 2006: 7: 653-676.

Bourbousson J, Seve C, McGarry T. Space-time coordination dynamics in basketball: Part 1. Intra- and inter-couplings among player dyads. J Sport Sci 2010a: 28: 339-347.

Bourbousson J, Seve C, McGarry T. Space-time coordination dynamics in basketball: Part 2. The interaction between the two teams. J Sport Sci 2010b: 28: 349-358.

Brito J, Krustrup P, Rebelo A. The influence of the playing surface on the exercise intensity of small-sided recreational soccer games. Hum Movement Sci 2012.

Buddenhagen J, Ford C, May M. Nice cubic polynomials, pythagorean triples, and the law of cosines. Math Mag 1992: 65: 244-249.

Coutts AJ, Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. J Sci Med Sport 2010: 13: 133-135.

Coutts AJ, Hill-Haas SV, Dawson B, Impellizzeri FM. Physiology of small-sided games training in Football a systematic review. Sports Med 2011: 41: 199-220.

Davids K, Araújo D, Button C, Renshaw I. Degenerate brains, indeterminate behavior and representative tasks: implication for experimental design in sport psychology research. In: Tenenbaum G, Eklund B, eds. *Handbook of Sport Psychology*. Hoboken, NJ: John Wiley, 2007.

Davids K, Araújo D, Shuttleworth R. Applications of dynamical systems theory to football. Science and football V 2005: 537-550.

Davids K, Button C, Araújo D, Renshaw I, Hristovski R. Movement Models from Sports Provide Representative Task Constraints for Studying Adaptive Behavior in Human Movement Systems. Adapt Beh 2006: 14: 73-95.

Dellal A, Chamari K, Pintus A, Girard O, Cotte T, Keller D. Heart Rate Responses during Small-Sided Games and Short Intermittent Running Training in Elite Soccer Players: A Comparative Study. J Strength Cond Res 2008: 22: 1449-1457.

Duarte R, Araújo D, Davids K, Travassos B, Gazimba V, Sampaio J. Interpersonal coordination tendencies shape 1-vs-1 sub-phase performance outcomes in youth soccer. J Sport Sci 2012a.

Duarte R, Araújo D, Freire L, Folgado H, Fernandes O, Davids K. Intra- and inter-group coordination patterns reveal collective behaviors of football players near the scoring zone. Hum Movement Sci 2012b.

Duclos Y, Burnet H, Schmied A, Rossi-Durand C. Approximate entropy of motoneuron firing patterns during a motor preparation task. J Neurosci Meth 2008: 172: 231-235.

Duffield R, Reid M, Baker J, Spratford W. Accuracy and reliability of GPS devices for measurement of movement patterns in confined spaces for court-based sports. J Sci Med Sport 2010: 13: 523-525.

Folgado H, Lemmink K, Frencken W, Sampaio J. Length, width and centroid distance as measures of teams tactical performance in youth football. Eur J Sport Sci 2012: iFirst article: 1-6.

Frencken W, De Poel H, Visscher C, Lemmink K. Variability of inter-team distances associated with match events in elite-standard soccer. J Sport Sci 2012: 30: 1207-1213.

Frencken W, Lemmink K. Team kinematics of small-sided soccer games: A systematic approach. In: Reilly T, Korkusuz F, eds. *Science and Footabll VI*. London: Routledge, 2008:161-166.

Frencken W, Lemmink K, Delleman N, Visscher C. Oscillations of centroid position and surface area of soccer teams in small-sided games. Eur J Sport Sci 2011: 11: 215-223.

GPSports. http://www.gpsports.com/. [accessed, 28.12.08] 2008.

Grehaigne JF, Godbout P, Zerai Z. How the "rapport de forces" evolves in a soccer match: the dynamics of collective decisions in a complex system. Rev Psicol Deporte 2011: 20: 747-765.

Hughes M, Bartlett R. Performance analysis. J Sport Sci 2002: 20: 735-737.

Kannekens R, Elferink-Gemser MT, Visscher C. Positioning and deciding: key factors for talent development in soccer. Scand J Med Sci Spor 2011: 21: 846-852.

Lames M, Ertmer J, Walter F. Oscillations in football - order and disorder in spatial interactions between the two teams. Int J Sport Psychol 2010: 41: 85-86.

Lames M, McGarry T. On the search for reliable performance indicators in game sports. Int J Perf Anal Sport 2007: 7: 16.

McGarry T, Anderson DI, Wallace SA, Hughes MD, Franks IM. Sport competition as a dynamical self-organizing system. J Sport Sci 2002: 20: 771-781.

Nevill AM, Atkinson G, Hughes MD, Cooper SM. Statistical methods for analysing discrete and categorical data recorded in performance analysis. J Sport Sci 2002: 20: 829-844.

Norton KI, Edgecomb SJ. Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian Football. J Sci Med Sport 2006: 9: 25-32.

Ouellette J. Principles of play for soccer. Stategies: A Journal for Physical and Sport Educators 2004: 17: 26.

Pincus SM. Approximate Entropy as a Measure of System-Complexity. P Natl Acad Sci USA 1991: 88: 2297-2301.

Pincus SM, Goldberger AL. Physiological Time-Series Analysis - What Does Regularity Quantify. Am J Physiol 1994: 266: H1643-H1656.

Preatoni E, Ferrario M, Dona G, Hamill J, Rodano R. Motor variability in sports: A non-linear analysis of race walking. J Sport Sci 2010: 28: 1327-1336.

Sampaio J, Maçãs V. Measuring tactical behavior in Football. Int J Sports Med 2012: 1-7.

Stergiou N, Buzzi U, Kurz M, Heidel J. Non linear tools in human movement. In: Stergiou N, ed. *Innovative analysis of human movement*. Campaign, IL: Human Kinetics, 2004:63-90.

Travassos B, Araújo D, Duarte R, McGarry T. Spatiotemporal coordination behaviors in futsal (indoor football) are guided by informational game constrains. Hum Movement Sci 2012: 31: 932-945.

Travassos B, Araujo D, Vilar L, McGarry T. Interpersonal coordination and ball dynamics in futsal (indoor football). Hum Movement Sci 2011: 30: 1245-1259.

Vilar L, Araújo D, Davids K, Button C. The Role of Ecological Dynamics in Analysing Performance in Team Sports. Sports Med 2012: 42: 1-10.

Wade A. *Principles of Team Play*: Reedswain Inc, Spring City PA 1996.

CHAPTER 5

REGULARITY OF INTERPERSONAL COORDINATION DISCRIMINATES SHORT AND LONG SEQUENCES OF PLAY IN SMALL-SIDED FOOTBALL GAMES

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ABSTRACT

Objectives: To examine whether the structure underlying the interpersonal coordination tendencies can discriminate the length of possession sequences of play, using cluster analysis.

Design: Cross-sectional field study.

Methods: The data were gathered using global positional systems (5 Hz) in 5-a-sided games (3 bouts of 6 mins) performed by 10 elite U19 footballers. Tactical performance was measured using player-to-centroids (own and opponent team) distances, which were analysed with the non-linear statistical tool approximate entropy (ApEn). The sequences of play were classified using two-step cluster analysis. ANOVA models were used to analyse the Type of Relation (intra-team vs. inter-team coordination) and the Sequence of Play (short vs. long sequences).

Results: The irregularity of the player-to-centroids distances allowed the discrimination of two clusters, separating the short sequences (cluster one) from the long sequences (cluster two). Mixed-model ANOVAs revealed significant interaction effects of Type of Relation X Sequences of Play, $F(1,73) = 8.730$, $p \leq .004$ and, $F(1,73) = 13.058$, $p \leq .001$, independently of the variable taken as criterion to divide the clusters.

Conclusion: Intra- and inter-team interpersonal coordination tendencies discriminated short and long sequences of play during SSGs practice. Generally, short sequences of play displayed higher irregularity than the longer sequences. Longer sequences of play also showed a trend to higher unpredictable inter-team interactions compared to the interactions with teammates, while data showed an opposed trend to short sequences of play.

KEY WORDS: GPS, positioning variables, cluster analysis, ball possession

Submited

5.1. INTRODUCTION

Team sports performance can be seen as the result of a long term training process designed to improve players and teams' skills in order to face the complex and dynamic competition requirements[1]. Recent studies suggest that football match-performance depends on the effective interaction of technical, tactical and physical demands of the game[2]. In order to promote an effective interaction of these performance components the use of small-sided games (SSGs) has been implemented worldwide and are well documented[3]. The systematic exposure to SSGs during training sessions have been suggested to improve players' decision making, technical skills, tactical awareness and physical conditioning through functional movements[4, 5]. However, there is a lack of knowledge regarding the tactical requirements elicited by SSGs, and their corresponding transfer to match performance[3].

One important aspect related to tactics that has been systematically investigated in the last years is ball possession[6]. Several studies reported significant differences in ball possession characteristics such as number of passes per possession[7, 8], duration[7, 9] and starting zone[7, 10] between successful and unsuccessful teams, frequently moderated by the evolving match status[11, 12], venue[11] and the quality of opposition. Nevertheless, a recent study revealed that much of the success behind the 'possession game' was influenced by some elite teams confined geographically and competing in domestic leagues[6]. However, the influence that some of these elite teams (e.g., Spain, Barcelona, Manchester United) exert on the evolutionary trends of association football preserves the relevance of the possession game[6], at least, as a nuanced approach to account for variant strategic environments[6, 13].

Keeping the recommendation of Hill-Haas and co-workers[3], an examination of different possession strategies emerging during SSGs may provide a more adequate understanding of their effects, and the potential learning transfer to match performance. Recent criticisms, however, have been pointed to the use of one-dimensional quantitative data methodologies (e.g., frequencies or counts of match events), since it fails to provide enough information about the performance context[14] and to capture the interpersonal interaction tendencies of players[15, 16]. Since notating discrete actions or events may exclude important characteristics of effective possessions, here we integrate continuous positional time-series data from players' movement trajectories to overcome the mentioned limitations. Our assumption is that teams' possessions are dependent upon how players are dynamically positioned according to the teams' overall space distributions and the dynamics of interpersonal coordination tendencies evolving at local scales[16]. Therefore, understanding the structure underlying different possession strategies during SSGs should include the inter-players' relative positioning in the pitch. Recent studies proposed the use of the player-to-team centroid distances to capture the tactical behaviours emerging in SSGs conditions[1, 4]. Indeed, this coordination variable was a strong predictor of changes in pace, game status and team unbalance during SSGs practice[1].

However, there is still a lack of studies that attempted to identify the influence of interpersonal coordination dynamics in the teams' ball possession during SSGs practice. Therefore, the aim of this study was to examine whether the regularity of the players' interpersonal coordination tendencies can discriminate between short and long sequences of play. We hypothesised that, using cluster analysis, the structure underlying the interpersonal coordination tendencies should discriminate the length of possession sequences.

5.2. Methods

Ten male under 19 professional football players (age = 18.0 ± 0.67 years), with a mean of 10.20 ± 1.81 years of experience participated in this study. All players were members of the same youth team competing in the Portuguese, under 19 First Division. The team practiced 5 times per week, 90 minutes per session, with an official competition every weekend. Five of these players have already represented the National teams in youth international competitions. Furthermore, all these players practiced regularly with the professional team that competes in the Portuguese First League.

All players, their parents (when required), and the team supervisors were informed about the research procedures, requirements, benefits and risks, and their written consent was obtained before the study began. The study was approved by the Ethics Committee of the Research Centre for Sports Sciences, Health and Human Development, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal. The study protocol followed the guidelines laid down by the Declaration of Helsinki.

The SSGs were performed in the last 2 weeks of the competitive season. The best 10 players were selected and randomly divided in two teams using players' positions, tactical/technical levels, physical performance and participation in competitive matches[17].

Before the data collection sessions, a theoretical presentation was given in order to present and discuss the procedures with the participants. Also, an initial familiarization session was conducted with all the ten participants to prevent bias from novelty effects caused by the procedures and equipment.

Data were collected in two different sessions with a week of interval, maintaining the same teams' constitutions in the two sessions. The SSGs were performed at the beginning of each training session, following a standardized 20-min warm-up consisting of running, dynamic stretching and a ball possession game. In overall, the SSGs lasted 20-minutes, with 3 bouts of 6-minutes with 1-minute of active recovery. During the SSGs formal goals were used and a goalkeeper was added randomly to each team. The offside rule was not applied during the game and coach encouragement or feedback was not allowed during the activity. Field dimensions used during the 5-a-side SSG was 44x34m, in order to keep the relative area per player in 1:150m^2 [18].

The 5-a-side SSGs were recorded for later analysis using a Sony HDR-CX116E camcorder, placed in an elevated plane that allowed viewing the entire pitch. Players' movement displacements during the SSGs were measured using portable global positioning system units (SPI-PRO, GPSports, Canberra, ACT, Australia) at 5 Hz. The SPI-PRO was placed into a harness positioning the device between the player's shoulder blades[18]. The GPS is a satellite-based navigation system that enables gathering positional data during training and competition with several applications in field sports research[19, 20]. The accuracy of the SPI PRO is ~1-5% based on the manufacturer[21] and independent verification[19] of reliability and validity were established against criterion measures of speed and distance.

The positional data (x, y) extracted from latitude and longitude GPS coordinates allowed calculating both team and opponent team centroids (mean field position of all outfield players) and the following individual performance variables measured over time: i) Player-to-own centroid distance (CNT), which captured the absolute distance of each player to the geometrical centre of its team; ii) Player-to-opponent centroid distance (OPCNT), which captured the absolute distance of each player to the geometrical centre of the opponent team.

The digital video footages were analysed using a PC. All the stoppages of play were removed and only the sequences of play without changes in ball possession were selected. Next, each sequence was evaluated in the following dependent variables: i) Ball possession duration (seconds), any sequence of ball possession was defined from the moment a player gained possession for his team until the time that the team lost possession of the ball to the opponents; ii) Number of passes, number of consecutive passes in each offensive sequence of play before losing ball possession.

To avoid disagreement between competent observers, the match activities were scored by a single observer who previously showed a test-retest value upper than 95% of agreement[22] for each variable observed.

The data recorded by GPS (x and y coordinates) were exported to MATLAB® 6.5 (The Mathworks Inc., Natick, MA) for processing and analysis. To assess the regularity of player's movement patterns (i.e., the regularity in the variations of the distances to team and opponent team centroid), we calculated approximate entropy (ApEn) measures. According to the literature[23], ApEn is an adequate statistical procedure to analyse non-linear time series data that holds both deterministic and stochastic processes, as in biological signals. The ApEn algorithm quantifies regularity in a time series, by measuring the logarithmic likelihood that runs from patterns that are close to m contiguous observations remain close (within r tolerance) on subsequent incremental comparisons[23]. Input values of vector length (m) was 2.0 and the tolerance factor (r) was 0.2 standard deviations[24]. The obtained values are unit less real numbers ranging from 0 to 2, with low values corresponding to more regular and predictable sequences of data points[23]. In the present study, the ApEn values allowed quantifying the amount of regularity in the adjustments that each player performed with its teammates and opponents. Due to methodological purposes only ball possessions longer than 10 seconds were considered for further analysis, since reliable ApEn analysis needs a minimum of 50 data points[24]. Also, due to the different length of the time-series from each selected sequence of play, ApEn ratio random values were computed using Matlab. These normalised values comprised a ratio calculated from the ApEn value for the original time-series divided by the average of the ApEn values calculated from 100 normally distributed random time-series[16]. A total of 75 offensive sequences of play were further analysed.

Two-step cluster analysis with log-likelihood as the distance measure and Schwartz's Bayesian criterion was performed twice to classify the offensive sequences according to the ApEn values of players' distances to: i) own team centroid and, ii) opponent team centroid. One-way ANOVAs were used to compare the distance of each player to the own team centroid and opponent team centroid (meters and ApEn), duration of each ball possession and the number of passes per possession between the two clusters previously found. Two mixed-model ANOVAs were performed on the player to centroid distance ApEn values with Type of Relation (intra-team vs. inter-team coordination) as within-participants factor and Sequence of Play (short vs. long sequences) as between-participants factor. Violations of the sphericity assumption for the within-participants factor were checked using Mauchly's test of sphericity. When a violation was apparent, the Greenhouse–Geisser correction procedure was used to adjust the degrees of freedom. Effect sizes were measured as partial eta squared (η^2). The level of statistical significance was set at $p \leq 0.05$. All statistical analyses were performed using the software IBM SPSS 20.0 (SPSS Inc., Chicago, IL, USA).

5.3. Results

The cluster analyses found two distinct groups of offensive sequences of play according to the ApEn values of CNT and OPCNT, separately used as criterion variable. In both analyses, the cluster one (short offensive sequences) is smaller than the cluster two (long offensive sequences), comprising 32% and 26% of the sample size and 68% and 74%, respectively.

Figure 5.1 presents the relative distribution of each cluster group in the considered variables (CNT and OPCNT ApEn) and the respective input predictor importance (PI).

The presented results showed that when CNT was the variable taking into account to clustering, the player with the higher PI was the player 9 (1.00) followed by player 5 (PI=0.94) while the lowest PI was assigned to player 2 (0.33). In the other hand, when the OPCNT was taking as criterion, player 5 presented the highest PI (1.00) followed by player 1 (0.84) and the player with the lowest PI were the number 3 (0.28).

Table 5.1 presents the one-way ANOVA comparisons between the two groups (short and long offensive sequences) for all the dependent variables. When the clusters were calculated using the CNT ApEn values, significant differences were found in all variables with exception of both distance to CNT and OPCNT in meters. The same results were reached to all variables when the OPCNT was used to define the clusters (Table 5.1).

Mixed-model ANOVAs revealed significant Type of Relation X Sequences of Play interaction effects, $F(1,73) = 8.730$, $p \leq .004$, $\eta^2 = .111$ and, $F(1,73) = 13.058$, $p \leq .001$, $\eta^2 = .157$, independently of the variable taken as criterion to divide the clusters. There are no main effects of the Type of Relation on the ApEn values, $F(1,73) = .763$, $p \leq .385$, $\eta^2 = .011$. Mean data reported in Table 5.1 allows understand that ApEn values of CNT (0.72±0.15) were higher than OPCNT (0.69±0.15) for the short sequences of play (cluster 1), but in the long sequences (cluster 2) the ApEn values of CNT (0.49±0.11) were low than the values of OPCNT (0.52±0.11).

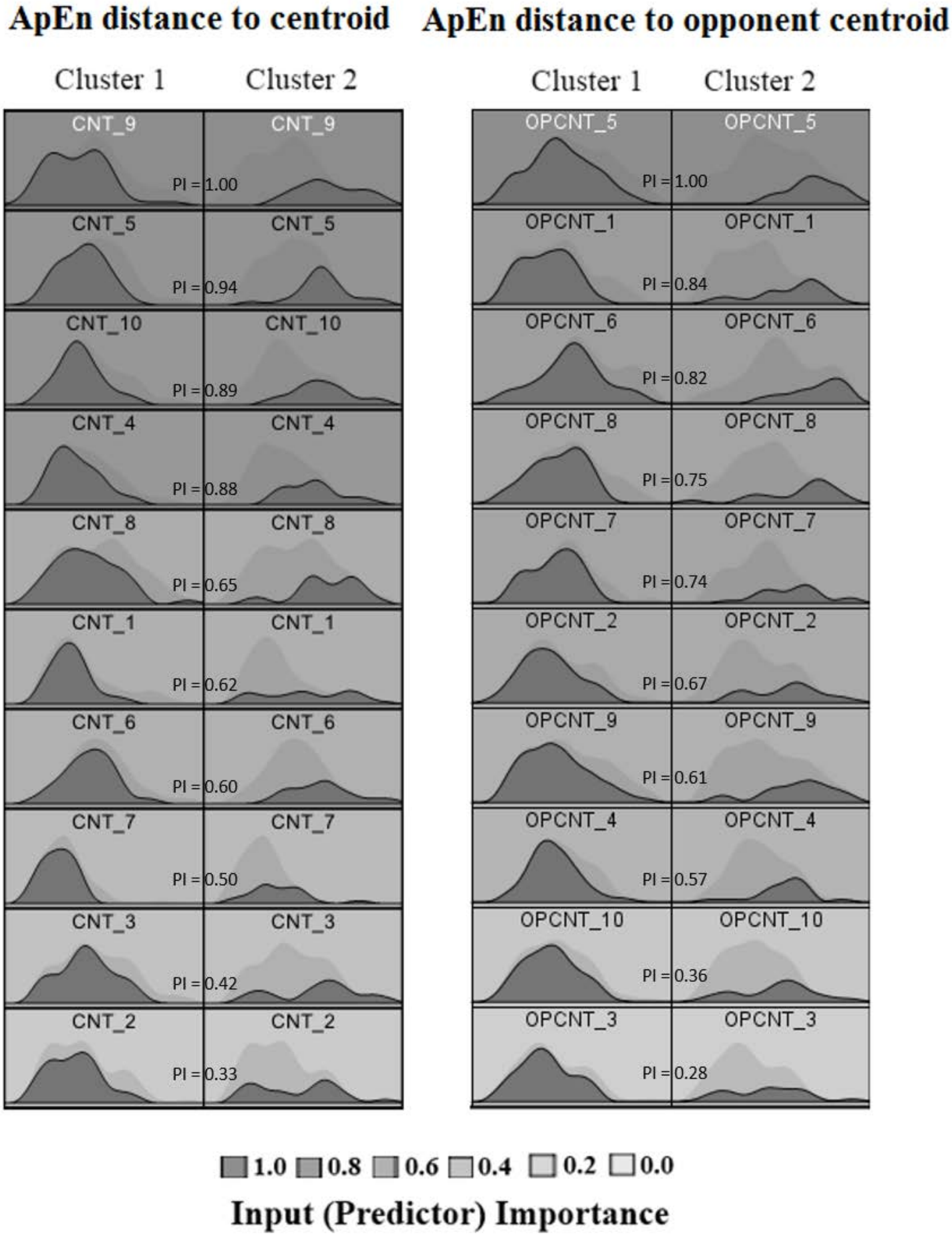

Figure 5.1 - Relative distribution of each cluster group in the considered variables (players' distances to the own team centroid and the opponent team centroid). PI = predictor importance.

Table 5.1 - Comparisons of all dependent variables (mean ± SD) between the short offensive sequences (cluster 1) and the long offensive sequences (cluster 2).

		Cluster		F	*p*	η^2
		1 (n=24, 32%)	2 (n=51, 68%)			
Own Team centroid	Distances to centroid					
	Meters	7.78±1.64	7.80±2.09	2.4	.07	.09
	ApEn	0.72±0.15	0.49±0.11	46.6	.00	.66
	Distances to opponent centroid					
	Meters	9.66±1.98	9.80±2.44	0.7	.58	.03
	ApEn	0.69±0.15	0.52±0.11	39.4	.00	.63
	Ball Possession (sec)	13.42±5.21	21.80±10.55	13.5	.00	.16
	Number of passes (n)	3.67±1.93	5.59±2.96	8.4	.00	.10
		1 (n=20, 26%)	2 (n=55, 74%)			
Opponent team centroid	Distances to centroid					
	Meters	7.79±1.59	7.80±2.07	0.0	.97	.00
	ApEn	0.75±0.12	0.50±0.11	70.0	.00	.49
	Distances to opponent centroid					
	Meters	9.42±195	9.88±2.42	1.95	.17	.03
	ApEn	0.72±0.14	0.52±0.11	48.26	.00	.40
	Ball Possession (sec)	12.30±3.50	21.60±10.40	15.26	.00	.17
	Number of passes (n)	3.35±1.63	5.56±2.92	10.3	.00	.12

5.4. Discussion

The aim of this study was to examine whether the regularity of players' interpersonal interactions allowed discriminating between short and long sequences of play during SSGs practice. The cluster analyses based on ApEn measures of the players' distances to teams' centroids (CNT and OPCNT) were able to discriminate consistently the short from the long sequences of play. The number of sequences of play obtained in each cluster was very similar independently of the variable taken as criterion (i.e., CNT or OPCNT). Indeed, only 4 sequences of play varied between the two analyses.

The individual PI data obtained with the cluster analyses suggest that players have different behavioural strategies supported by distinct informational game constraints[25]. For instance, player 9 presented a higher PI when CNT was the variable taken as criterion to create the clusters. This means, hypothetically, his behaviour is guided by perception-action couplings more associated with informational constraints emerging from intra-team coordination tendencies. On the contrary, player 1 had higher PI when OPCNT was taken as the criterion variable, which might means he guided his behaviour based on informational constraints emerging mainly from inter-team coordination. Results showed also that some other players presented similar PIs values in the two cases (e.g. player 5), suggesting a simultaneous use of both intra- and inter-team coordination tendencies as relevant sources of information to guide their behaviours.

Our aggregated analyses showed significantly higher irregularity both in the intra- and inter-team interpersonal coordination of short sequences of play than in the long sequences. Interestingly, the absolute distances did not vary between the two types of sequences of play. These findings suggest the existence of a different hidden structure underlying interpersonal coordination dynamics during short and long sequences of play[26, 27]. More specifically, the less predictable inter-players' behaviours in the short sequences of play may reveal a tendency to solve these game scenarios based on creative and novelty interpersonal solutions. On the other hand, long sequences of play seem more prone to evolve based on higher stable inter-players' coordination patterns. Sampaio and Maçãs[1] have demonstrated that increased expertise in football implied an increase in the stability of these inter-players' coordination variables. Our data suggests that, probably, the stability reported by the authors was due to an increase in the duration of the sequences of play.

In the current study we captured not only intra-team interpersonal coordination tendencies like in previous studies (e.g., Sampaio et al.[28]) but also inter-team coordination. Our analyses revealed significant interaction effects between Type of Relation X Sequences of Play. More precisely, irregularity of intra-team interpersonal coordination was higher than of inter-team coordination tendencies for short sequences of play, while in the long sequences of play the results were opposed. A previous work of Hughes and Franks[8] showed that international successful teams tend to produce more goals per possession when using longer passing sequences compared to shorter passing sequences. The current work shed some light into how players forge-and-broke interpersonal interactions with teammates and opponents[29] in these different prototypical sequences of play. Our findings suggested that players tend to explore more unpredictable interpersonal interactions with teammates than with the opponents during short sequences of play. On the other hand, during long sequences of play players tend to stabilize their interactions with teammates and to exploit higher irregular and unpredictable interpersonal interactions with their opponents. In the current study, taking ApEn values of CNT allowed us obtaining 4 players with PI above 0.8 while using ApEn values of OPCNT only gave 3 players above this threshold. The PI values indicated the relative importance of each player in estimating the model. The large effect sizes displayed for

ApEn values of CNT, in both analyses, suggested also that, in the current study, this is the more suitable variable to take as criterion.

5.5. Conclusion

The current study revealed the intra- and inter-team interpersonal coordination tendencies underlying short and long sequences of play during SSGs practice. The short sequences of play showed higher irregularity than the longer sequences of play. Moreover, in the short sequences there was a trend to higher unpredictable intra-team interpersonal interactions when compared with the interactions with the opponent team players. However, the longer sequences of play showed a trend to higher unpredictable inter-team interactions compared to the interactions with teammates. In a coaching perspective, these findings can be useful for instructional purposes, namely in the design of practice tasks setting the appropriate constraints to promote either short or long offensive sequences of play.

5.6. Practical implications

- Clustering methods based on non-linear analyses of interpersonal coordination variables can be useful to discriminate between relevant playing styles and performance contexts.
- Promoting an elaborated game approach with long sequences of play imply a relative stabilization of intra-team interpersonal interactions and the exploitation of unpredictable interactions with opponent team players.
- Promoting a direct playing style with short sequences of play before shooting imply higher irregularity of on-field interpersonal interactions, especially in the intra-team coordination tendencies.

5.7. References

1. Sampaio J, Maçãs V. Measuring tactical behavior in Football. *Int J Sports Med* 2012; (33):1-7.
2. Dellal A, Owenc A, Wonge D et al. Technical and physical demands of small vs. large sided games in relation to playing position in elite soccer. *Hum Movement Sci* 2012.
3. Hill-Haas SV, Dawson B, Impellizzeri FM et al. Physiology of Small-Sided Games Training in Football A Systematic Review. *Sports Med* 2011; 41(3):199-220.
4. Folgado H, Lemmink K, Frencken W et al. Length, width and centroid distance as measures of teams tactical performance in youth football. *Eur J Sport Sci* 2012; iFirst article:1-6.
5. Aguiar M, Botelho G, Lago C et al. A Review on the Effects of Soccer Small-Sided Games. *J Human Kinetics* 2012; 33:103–113.

6. Collet C. The possession game? A comparative analysis of ball retention and team success in European and international football, 2007–2010. *J Sport Sci* 2012; 31(2):123-136.
7. Tenga A, Sigmundstad E. Characteristics of goal-scoring possessions in open play: Comparing the top, in-between and bottom teams from professional soccer league. *Int J PerfAnal Sport* 2011; 11(3):545-552.
8. Hughes M, Franks I. Analysis of passing sequences, shots and goals in soccer. *J Sport Sci* 2005; 23(5):509-514.
9. Hughes M, Churchill S. Attacking profiles of successful and unsuccessful teams in Copa America 2001. *J Sport Sci* 2004; 22:505.
10. Garganta J, Maia J, Basto F, *Analysis of goal-scoring patterns in European top level soccer teams,* in *Science and Football III*, T. Reilly, J. Bangsbo, and M. Hughes, Editors. 1997, E & FN SPON: London. p. 246-250.
11. Lago C, Martin R. Determinants of possession of the ball in soccer. *J Sports Sci* 2007; 25(9):969-74.
12. Lago-Penas C, Dellal A. Ball Possession Strategies in Elite Soccer According to the Evolution of the Match-Score: the Influence of Situational Variables. *J Hum Kinet* 2010; 25:93-100.
13. James N, Mellalieu S, Holley C. Analysis of strategies in soccer as a function of European and domestic competition. *Int J Perf Anal Sports Medicine* 2002; 2:85-103.
14. James N. Notational analysis in soccer: past, present and future. *Int J Perf Anal Sport* 2006; 6:67-81.
15. Tenga A, Kanstad D, Ronglan LT et al. Developing a new method for team match performance analysis in professional soccer and testing its reliability. *Int J Perf Anal Sport* 2009; 9(1):8-25.
16. Duarte R, Araujo D, Davids K et al. Interpersonal coordination tendencies shape 1-vs-1 sub-phase performance outcomes in youth soccer. *J Sport Sci* 2012; 30(9):871-877.
17. Castellano J, Casamichana D. Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *J Sport Sci* 2010; 28(14):1615-1623.
18. Hill-Haas SV, Dawson BT, Coutts AJ et al. Physiological responses and time-motion characteristics of various small-sided soccer games in youth players. *J Sport Sci* 2009; 27(1):1-8.
19. Coutts AJ, Duffield R. Validity and reliability of GPS devices for measuring movement demands of team sports. *J Sci Med Sport* 2010; 13(1):133-135.
20. Frencken W, Lemmink K, *Team kinematics of small-sided soccer games: a systematic approach.*, in *Science and Soccer VI*, T.R.F.K. (Eds.), Editor 2008, Routledge: London. p. 161-166.
21. GPSports. http://www.gpsports.com/. *[accessed, 28.12.08]* 2008.
22. Clark JM, Elble RJ, Hughes LF. Performance of third and fourth year medical students during the neurology clerkship. *Neurology* 2002; 58(7):A21-A21.
23. Pincus SM. Approximate entropy as a measure of system-complexity. *P Natl Acad Sci USA* 1991; 88(6):2297-2301.
24. Stergiou N, Buzzi U, Kurz M et al., *Non linear tools in human movement.*, in *Innovative analysis of human movement.*, N. Stergiou, Editor 2004, Human Kinetics: Campaign, IL. p. 63-90.
25. Travassos B, Araujo D, Duarte R et al. Spatiotemporal coordination behaviors in futsal (indoor football) are guided by informational game constraints. *Hum Movement Sci* 2012; 31(4):932-945.

26. Glazier PS, Davids K. On analysing and interpreting variability in motor output. *J Sci Med Sport* 2009; 12(4):e2-3; author reply e4-5.

27. Harbourne RT, Stergiou N. Movement variability and the use of nonlinear tools: principles to guide physical therapist practice. *Physical therapy* 2009; 89(3):267-82.

28. Sampaio JE, Lago C, Gonçalves B et al. Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *J Sci Med Sport* (0).

29. McGarry T, Anderson DI, Wallace SA et al. Sport competition as a dynamical self-organizing system. *J Sport Sci* 2002; 20(10):771-781.

CHAPTER 6

The aim of this thesis was to characterize small-sided games (SSG) as a football training tasks with special focus to the player's number manipulation constraint. The studies included in this thesis allowed achieving an understanding about how small-sided football games could be used as training stimulus to improve the footballer's performance. By characterize the physiological, perceptual, activity profiles and tactical requirements of four SSG (2-, 3-, 4- and 5-a-side) our study improved the knowledge about how these characteristics are influenced by changing the player's number.

6.1. CONCLUSIONS OVERVIEW

In chapter two a critically literature review about SSG was done. This review reveals a lack of consistency in SSG design, player's fitness, age, ability, level of coach encouragement, and playing rules, which make difficult to get accurate conclusions on the influence of each of these factors separately. This opened a window to our following studies on the physiological, perceptual, time-motion and dynamical players response to different SSG formats keeping the ratio player:area constant in about $150m^2$ and using the same players across all the proposed designs.

In chapter three, players' physiological, perceptual responses and activity profiles in four different SSG were described. Our results showed higher physiological and perceptual responses in the smaller SSG formats. Furthermore, the activity profiles reveals that the total distance performed was similar across the three larger formats, while in the 2-a-side is significantly smaller. The 3-a-side format presents also a larger distance performed above 18 $Km.h^{-1}$. The 4- and 5-a-side formats presented similar number of sprints. The body load measured across the SSG formats increases with the number of players until de 4-a-side and decreases to lower values that those obtained in the 2-a-side format. Moreover, the body load per minute values decreases each two minutes of game play. In fact, the results obtained suggest that the small game formats are more appropriate to increase physiological stress, while larger formats can be used to improve match-specific demands.

The emergent coordination processes, displayed by players during the four SSG formats were investigated in chapter four. Focused on different variables, this study demonstrated how within- and between team players relationship varies with the number of players of each SSG format. Our results showed that the absolute distance to the team centroid increased with the players' number. The same happens with the predictability of this distance shoed by the ApEn values. Moreover, absolute distance to the opponent team centroid was higher than the absolute distance to own team centroid and increased with the players' number. Results also reveal that within each SSG format, the players presented high stability of distances to the team centroid. By other side, the distance between centroids decreased from 2- to 4-a-side and increased to the highest distance in 5-a-side. This format presents also a more homogenous angle distribution between 0º and 180º compared with all smaller formats in study. The results suggested that the larger formats (4- and 5-a-side) are the most suitable formats to promote emergent self-organized behaviours. Moreover, our results provided evidence on how the positioning variables across different small-sided games can be a strong candidate to describe the players and teams' tactical behaviour.

Once the previous results suggest that the 5-a-side format is the most suitable format to develop match specific demands, in chapter five we focused our attention on this format. In this chapter we tried to examine whether the structure underlying the interpersonal coordination tendencies can discriminate the length of possession sequences of play. The cluster analyses based on ApEn measures of the players' distances to teams' centroids discriminate consistently the short from the long sequences of play. The aggregated analyses performed showed significantly higher irregularity in both intra- and inter-team interpersonal coordination of short sequences of play than in the long sequences. Interestingly, the absolute distances did not vary between the two types of sequences of play. These findings suggest the existence of a different hidden structure underlying interpersonal coordination dynamics during short and long sequences of play. Our analyses also revealed significant interaction effects between Type of Relation and Sequences of Play. More precisely, irregularity of intra-team interpersonal coordination was higher than the inter-team coordination tendencies for short sequences of play, while in the long sequences of play the results were opposed. Accordingly, intra- and inter-team interpersonal coordination tendencies discriminated short and long sequences of play during SSGs practice. Generally, short sequences of play displayed higher irregularity than the longer sequences. Longer sequences of play also showed a trend to higher unpredictable inter-team interactions compared to the interactions with teammates, while data showed an opposed trend to short sequences of play.

In summary, this thesis allowed to better understand the player's number effect on small-sided games outcome. The results clearly indicate that smaller SSG formats are more suitable to work physiological demands and to increase the unpredictability in player's actions. Instead, the larger formats permit to develop the match specific demands and develop the player's ability to assume more predictable behaviours in their action, which leads to a strongest team commitment.

6.2. PRACTICAL APPLICATIONS

Chapter three presented players' physiological, perceptual responses and activity profiles in four different SSG formats. Results indicate that smaller formats are more appropriate to increase physiological stress, while larger formats can be used to improve match-specific demands. This information is useful for coaches, since they can modify or introduce rules in the SSG formats to adjust them to the competition demands. While maintaining a constant area:player ratio, coaches can use lower number of players (2- and 3-a-side) to increase cardiovascular demands, but higher number of players (4- and 5-a-side) to increase variability and specificity. The body load is influenced by the SSG formats, with the results suggesting that coaches can manipulate the duration of play in 2 minutes blocks to preserve the exercise intensity. Activity profile and body load were not as different as expected, however, 4-a-side game format presented higher values and higher variability and, again, the 3-a-side game format was the most stable format. This information allows to the coach to select the SSG format according to their conditioning purposes.

Chapter four showed that the positioning variables across different SSG showed to be powerful to describe the players and teams' tactical behaviour. By knowing and understanding the absolute distance between players, coaches may plan and monitor the training drills more accurately. For example, distance to team centroid can indicate what kind of pass players should perform during the training session to improve their performance. Moreover, our results allow coaches to decide which SSG format is more suitable to achieve their objectives once, with less number of players, the unpredictability is increased. On the other side, in larger formats, the players seem to use a higher level of organization and a more rational space occupation that in turn leads to a more stable behaviour of the players in these SSG formats.

Chapter five offered significant information about how the structure underlying the interpersonal coordination tendencies can discriminate the duration of possession sequences of play. The results showed that if a team assume an elaborated game approach with long sequences of play it imply a relative stabilization of intra-team interpersonal interactions and the exploitation of unpredictable interactions with opponent team players. Conversely, if a direct playing style with short sequences of play before shooting is adopted, this imply higher irregularity of on-field interpersonal interactions, especially in the intra-team coordination tendencies. Taking into account this information, the coach can use these findings for instructional purposes, namely in the design of practice tasks setting the appropriate constraints to promote either short or long offensive sequences of play, i.e., drawing their team playing style. The schematisation of the main practical aplications derived from the results of this thesis are presented in figure 6.1.

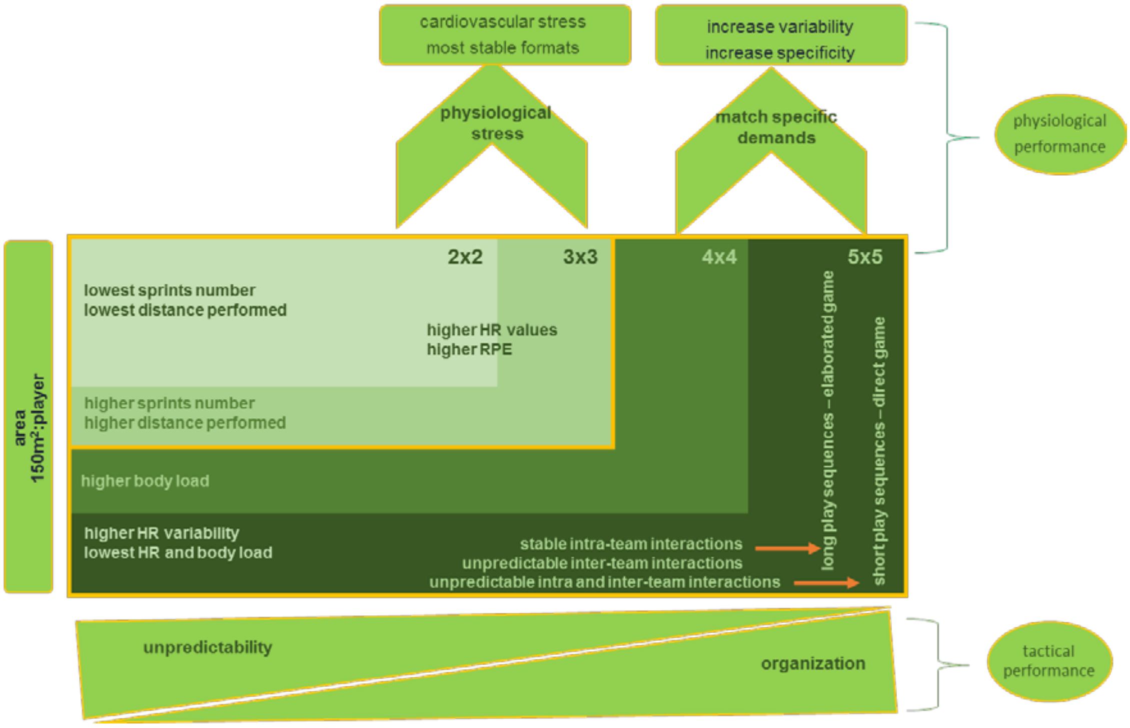

Figure 6.1. Organisation of the main practical applications derived from the results reached during this thesis.