Competitive design in youth soccer:

Assessing the influence of game constraints on players´ performance.

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Na presente tese procura-se fornecer demonstrações empíricas e orientações pedagógicas para a compreensão e modelação do contexto formal do jogo de futebol em relação às caraterísticas dos jogadores, indagando se os constrangimentos estruturais e funcionais da competição (superfície do campo, formato de jogo, e escalão etário) promovem assimetrias na performance física, técnica e tática dos jovens jogadores. Ainda há pouca evidência científica sobre as mudanças produzidas no desempenho dos jogadores e equipas devido ao efeito dos constrangimentos estruturais e funcionais da competição infanto-juvenil. Assim, é difícil justificar se jogos de futebol das competições infanto-juvenis são realizados em condições de jogo adaptadas ao nível de habilidade e idade dos jogadores. Por conseguinte, pretendeu-se perceber que tipo de formatos de jogo são utilizados nos campeonatos infanto-juvenis e como os respetivos formatos se correlacionam com a idade dos jogadores. Para tal, realizou-se um estudo com recurso a um teste de independência de Qui-Quadrado e um coeficiente de correlação ordinal de Spearman para correlacionar o escalão etário com os diferentes formatos de jogo utilizados nas competições infanto-juvenis. Posteriormente, considerando os formatos de jogo (5v5; 7v7; 9v9; e 11v11) e o tipo de superfícies de campo (relva natural; relva artificial; e terra batida) que são utilizados nos campeonatos infanto-juvenis, desenvolveram-se mais quatro estudos para indagar: (i) o efeito da superfície do campo na atividade locomotora e no desempenho técnico de jovens futebolistas; (ii) o efeito da superfície do campo no posicionamento e deslocamento de jovens futebolistas; (iii) o efeito do formato do jogo e escalão etário na atividade locomotora de jovens futebolistas; (iv) a influência dos formatos de jogo no posicionamento e deslocamento de jovens futebolistas durante o jogo. Os resultados encontrados permitiram constatar que os formatos de jogo mais utilizados na Europa (Estudo I) são o 5v5, 7v7, 9v9, e 11v11 mostrando uma correlação significativa com os escalões etários de U8, U10, U12, e U14 respetivamente (χ^2 (63) = 477,724; p <0,001), com um coeficiente de correlação de Spearman de (0.852). Os estudos (ii) e (iii) evidenciaram um efeito significativo da superfície do campo na atividade locomotora ($p < 0.05$), no desempenho técnico ($p < 0.001$) e no posicionamento ($p < 0.001$) e deslocamento ($p < 0.05$) dos jovens futebolistas. Relativamente aos estudos (iv) e (v) os resultados demonstraram que o formato de jogo e o escalão etário influenciam significativamente a atividade locomotora ($p < 0.001$) e o posicionamento ($p < 0.001$) e deslocamento ($p < 0.001$) dos jovens futebolistas. Podemos afirmar que a superfície de relva natural induz a diminuição da atividade locomotora dos futebolistas enquanto a relva artificial reflete maior atividade locomotora assim como um estilo de jogo mais estruturado do ponto de vista tático; a superfície de terra batida promove o insucesso na execução das ações técnicas enquanto a relva artificial promove o aumento de ações bem-sucedidas. Também podemos argumentar que o formato de 11v11 promove o aumento significativo da atividade locomotora e maior estabilidade na variabilidade do posicionamento e deslocamento dos futebolistas; os formatos de 5v5 e 7v7 induzem menor atividade locomotora assim como o aumento de movimentos e ações imprevisíveis. Também identificamos que em idades entre os 8-10 anos os futebolistas tendem a realizar movimentos longitudinais e laterais de maior amplitude comparativamente a futebolistas com 12-14 anos. O conhecimento mais preciso sobre as adaptações promovidas pelas superfícies do campo, formatos de jogo e escalões etários pode contribuir para que os treinadores utilizem ferramentas mais apropriadas no processo de formação de futebolistas. Além disso, pode ajudar os treinadores e instituições reguladoras nacionais a implementarem condições adequadas de prática em que as exigências do jogo sejam adequadas à idade e às caraterísticas desenvolvimentais dos jovens praticantes.

PALAVRAS-CHAVE: FUTEBOL, DESEMPENHO FÍSICO E TÉCNICO-TÁTICO, CONSTRANGIMENTOS DE JOGO, FORMATOS DE JOGO, SUPERFÍCIE DE CAMPO, ANÁLISE DA PERFORMANCE

Abstract

This thesis aims to provide empirical evidence and pedagogical guidelines for understanding and modelling the formal context of soccer matches. More specifically, it aims to investigate whether the structural and functional constraints of the competition induce asymmetries in the physical, technical and tactical performance of youth players. The lack of scientific evidence about the effect of game constraints (i.e. pitch surface, game format and age-group) on performance of young players, reflects many doubts about whether the competitive design that are being used in youth soccer are suitable to the characteristics and capacity of the participants. Thus, we proposed to understand what kind of game formats are used in the youth championships and how the respective formats correlate with the age of the players. For this, a study was performed using a Chi-Square independence test and Spearman´s ordinal correlation coefficient to correlate the age-group with the formats. Posteriorly, considering the game formats (5v5; 7v7; 9v9; and 11v11) and the type of pitch surfaces (natural turf; artificial turf; and dirt field) that are being used in the youth championships, four studies were carried out to investigate: (i) the effect of the pitch surface on running activity and technical performance of young soccer players; (ii) the effect of the pitch surface on the positioning and displacement of young players; (iii) the effect of the game format and age-group on running activity of young players; (iv) the influence of the game formats on the positioning and displacement of young soccer players during match-play. The following statistical procedures were used: Kolmogorov-Smirnov and Shapiro-Wilks parametric tests to test adherence to data normality; two-way analysis of variance (ANOVA) with repeated measures to quantify differences in means of dependent variables; Mauchly´s test of sphericity was performed to verify any violations of sphericity, which were corrected through the Greenhouse-Geisser adjustment; effect sizes were reported as partial eta squared (η^2) obtained with the ANOVAs. The results showed that the most widely used game formats in Europe (Study I) are the 5v5, 7v7, 9v9, and 11v11, showing a significant correlation with the U8, U10, U12, and U14 age-groups, respectively (χ^2 (63) = 477,724, $p < 0.001$), with a Spearman correlation coefficient of (0.852). Studies (ii) and (iii) showed a significant effect of pitch surface on running activity ($p < 0.05$), in the technical performance ($p <0.001$) and the positioning ($p < 0.001$) and displacement ($p < 0.05$) of young soccer players. The results of the studies (iv) and (v) showed that the game format and the age-group significantly influence running activity ($p < 0.001$) and the positioning ($p < 0.001$) and displacement ($p < 0.001$) of the young soccer players. Thus, we can argue that the natural turf surface induces a decrease in the players´ running activity while the artificial turf reflects greater running activity as well as a more tactically structured game style. Additionally, the dirt field surface promotes failure in the execution of technical actions while the artificial turf promotes the increase of successful actions. We can also argue that the 11v11 game format promotes a significant increase in running activity and greater stability in the positioning and displacement variability of the players. Finally, the 5v5 and 7v7 formats induce less running activity as well as the increase unintentional movements and actions. We also identified that the players of 8-10 years tend to perform longitudinal and lateral movements of greater amplitude compared to soccer players with 12-14 years. The most accurate knowledge about the adaptations induced by pitch surfaces, game formats and age-groups can contribute to the coaches use the most appropriate tools in the process of the players´ development. Moreover, can help the coaches and national bodies to implement appropriate conditions of practice in which the requirements of the game are appropriate to the age and characteristics of the players.

KEYWORDS: FOOTBALL, PHYSICAL AND TECHNICAL-TACTICAL PERFORMANCE, GAME CONSTRAINTS, GAME FORMATS, PITCH SURFACE, PERFORMANCE ANALYSIS

CHAPTER I

Introduction

Introduction

Youth competitive stages in soccer

Association football, otherwise known as soccer, is a cultural phenomenon of high impact on a global scale. Thus, it is not surprising that number of practitioners has increased exponentially in recent decades, especially along development stages of youth players (Rocha, Bartholo, Melo, & Soares, 2011), which ranges from ~6 to ~18 years old and includes the initiation, preparation and improvement stages (Vegas, 2006). The focus on development stages of youth players has grown since the financial implications of "spotting a future talent" have encouraged coaches, parents, administrators and government bodies to support soccer development programmes (Stratton, Reilly, Williams, & Richardson, 2004). According to mentioned authors, the development programmes for soccer have two major goals: (i) to engage players in lifelong participation in the sport; and (ii) to maintain a professional outlook that continues to inspire and motivate young´s to participate. In this context, it becomes essential to use effective training and competition settings that motivate young´s to continue practicing and improving during their development process.

In youth soccer competitive stages, players are distributed by annual age-groups based on date of birth, i.e. chronological age (Figueiredo, Gonçalves, Coelho e Silva, & Malina, 2009) using specific cut-off dates (e.g. 1 January in Portugal). This criterion was defined with purpose of progressively exposing the young players to the increase of training requirements and competitive demands of respective stage (Folgado, Caixinha, Sampaio, & Maçãs, 2006). Youth competitive stages also follow a progressive configuration, season by season, using annual cut-off date proportional to the age of participants and defined as a specific category. In Portugal, these stages are ordered by the following categories: *Petizes* (6-7 years); *Traquinas* (8-9 yrs); *Sub-10* (10 yrs); *Sub-11* (11 yrs); *Sub-12* (12 yrs); *Sub-13* (13 yrs); *Juniores D* (12-13 yrs); *Juniores C* (14-15 yrs); *Juniores B* (16-17 yrs); and *Juniores A* (18-19 years) respectively. In this framework, one of the main purposes of National Federations is to expose the participants to training and match-play situations in the correct environment so that their skill and technique are developed.

Being able to match training requirements and competition to the stage of development of young´s requires a detailed multidisciplinary awareness of psychology, physiology and sociology as well as a clear understanding of the process of growth and development (Stratton et al., 2004). However, this task is complex since young´s are growing, developing and maturing at different rates and at different stages of development. In this context, it becomes determinant to progressively adapt the competitive requirements to the young practitioners through a structural model balanced and appropriate to their characteristics. According to Vegas (2006), the structure of a balanced competitive model should facilitate the accomplishment of a longitudinal planning based on stages or objectives. In this context, to ensure that participation of young players in competitive events is positive, it becomes essential that such events be sustained from a formative perspective and appropriate to the characteristics of participants (Arana, Lapresa, Garzón, & Álvarez, 2004). Concomitantly, it is necessary to consider the conditions of competitive events when analysing the performance of the players and teams. The information resulting from respective analysis can be useful for coaches and administrators.

The role of structural and functional constraints in youth soccer competitions: preview of the problem

The performance in soccer match context is governed by a complex interaction of variables, such as physiological fitness, psychological preparedness, physical development, biomechanical proficiency, and tactical awareness, amongst others (Rein, Perl, & Memmert, 2017). Besides the influence of these variables, it may be considered that performance also emerges from specific game constraints as players and teams seek to achieve their main goals (Bangsbo, 1994; Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Brito, Krustrup, & Rebelo, 2012; Clemente, Couceiro, Martins, & Mendes, 2012; Sarmento, Anguera, Pereira, & Araújo, 2018). For instance, environmental conditions, players´ level performance, positional role and tactics, strategies and style of play used by the team are some examples of factors that may represent specific game constraints on the players´ performance and ultimately the teams during match-play (Figueiredo et al., 2009).

In movement science, constraints have emerged as a central construct in the dynamical systems theoretical approach to motor control and learning (Glazier, 2017). Newell (1986) outlined a model of three categories of constraint (i.e. organismic, environmental and task) which combine to channel and guide the emergent patterns of coordination and control that ultimately determine performance outcome: i) Organismic constraint is reflected in the characteristics evidenced by the players, namely those constraints imposed physically, physiologically, morphologically or psychologically (McGinnis & Newell, 1982); ii) Environmental constraints are those constraints that are external to the movement system and that relate to the spatial and temporal layout of the surrounding world (Glazier, 2017). Game format, pitch size, pitch surface are some examples of environmental constraints and that fall within the scope of our study; iii) Task constraints are specific to an action or task to be performed and are related to the purpose of the respective action or task and the rules that governing them. Shooting distance during a basketball match or imposing a one-touch rule within a simulated football match during a training session are some examples of task constraints (Glazier, 2017).

Since the purpose of this thesis is to investigate the effect of the constraints imposed by the conditions under which the competitive games take place (i.e. the effect of game constraints) it becomes important to circumscribe the respective constraints. Thus, and with the purpose of circumscribing the main game constraints, Gréhaigne, Bouthier, and David (1997) proposed their segmentation in two dimensions: i) the structural dimension; and ii) the functional dimension. The first dimension expresses: (a) the pitch characteristics (e.g. pitch size, pitch surface, ...); (b) elements which may be counted and grouped into categories (e.g. the number of players; the players positioning,…); (c) a communication network which allows energy and information exchanges (e.g. the rules, the code play, a common frame of reference in order to read and interpret plays in the same way…). The second dimension expresses: (a) flows of energy, information, or elements moving about (e.g. players movement, ball trajectory, replacements, state of fatigue...); b) gates controlling the rate of various flows (e.g. the play leader, players´ momentary tactical choices, the referee, player age…); c) flows of movement (e.g. positioning and displacement of players, creating open space, restoring a defensive block…), adapted from (Gréhaigne et al., 1997).

The main purpose of National Football Federations (e.g. Portugal) is to optimise the formal conditions of sports practice. To achieve the mentioned purpose, the Federations adopted the principle to progressively increase the number of players, the game format and the pitch dimensions during development stages (Figueiredo et al., 2009). However, many doubts persist as to whether this principle is being achieved, particularly in Portugal.

For instance, in the Portuguese youth soccer competitions it is common to find young players (12 and/or 13 years old) performing soccer matches in 11v11 game format in soccer pitches with the maximum dimensions of length and width (Brito, 2016). However, according to Capranica, Tessitore, Guidetti, and Figura (2001) these game conditions are not suitable from the pedagogical point of view for the age and the capacity of the players. In this framework, we asked if such game conditions will not reflect a constraint on the players´ performance?

Moreover, Portuguese youth soccer competitions are also being performed under the effect of other specific structural and regulatory variables, such as the pitch surface, the game format and the age of the players.

Relative to the pitch surface, soccer matches are being performed on 3 different surfaces, i.e. natural turf, artificial turf and dirt field (FPF, 2017). Making a retrospective until the 2012-2013 season, we found that (56.6%) of soccer matches were performed in dirt field, being the artificial turf and the natural turf used in (33.1%) and (10.3%) of the matches. From the 2012-2013 to 2016-2017 season emerged the artificial turf as the most used pitch surface (62.5%), being the dirt field and the natural turf used in (29.4%) and (8.1%) of the matches, respectively (Brito, Roriz, Silva, Duarte, & Garganta, 2017). Despite this, it is not clear how young soccer players respond to the game requirements under the effect of each pitch surface. In this sense, there will be important differences in physical, technical and tactical performance of the players during soccer matches performed on different surfaces? The few available data concerning the effect of pitch surface on the performance indicators of the players suggest contradiction.

Previous research suggested that pitch surface neither influences tactical performance (Santos, Dias, Garganta, & Costa, 2013), nor the players´ movement patterns (Andersson, Ekblom, & Krustrup, 2008). On the other hand, there is evidence that natural turf induces an increase in the number of successful passes compared to the sand surface (Folgado, Duarte, Laranjo, Sampaio, & Fernandes, 2007) as well as ball possession and number of passes is 20% higher in artificial turf condition compared to the natural turf (Andersson et al., 2008). From a physical and physiological perspective, previous investigation has suggested that there are differences in running speeds, heart rate, blood lactate levels and perceived exertion of soccer players during soccer matches performed under the effect of three pitch surface conditions, i.e. sand, artificial turf and asphalt (Brito et al., 2012). Additionally, Binnie et al. (2014) investigated the training benefits of sand surface vs. natural turf and concluded that the use of sand surfaces in a pre-season training plan can improve the athlete´s preparation by maximizing the training response and reducing performance-limiting effects that may arise from heavy training loads on firm surfaces.

Concerning the game format and age-group, the soccer matches of youth competitions are being performed on 4 different formats (i.e. 5v5, 7v7, 9v9, 11v11), which in turn are used in specific age-groups. Making a retrospective until the 2012-2013 season, we check that the youth soccer matches were performed in 7v7 game format until the Under-13 age-group and from this age-group onwards the respective soccer matches were performed in 11v11 format. More recently (i.e. in 2016-2017 season) the 5v5 and 9v9 game formats began to be used by some associations. From table 1, we can check in detail the type of game formats and the respective age-group which are being used in the twenty-two Portuguese Football Associations.

Table 1. Portuguese Football Associations (%) that use each game format at each age. (Brito, 2016).

Age-groups	Game formats: 5v5	7v7	9v9	11v11
U7	4.5%			
U8	9.1%	4.5%		
U9		18.2%		
U10		68.2%		
U11		81.8%		
U12		95.5%	4.5%	
U13		95.5%	27%	18%
U14				100%

Note: 100% corresponds to 22 Football Associations

Despite this information, little is known about the game formats that are being used in the other European countries. Moreover, since most of previous research has been conducted on small-side-games context (Brandes, Heitmann, & Müller, 2012; Castellano, Casamichana, & Dellal, 2013; Dellal et al., 2012; Hill-Haas, Dawson, Coutts, & Rowsell, 2009), many doubts persist upon demands imposed by different game formats on young players performance in context of the youth soccer competitions (Capranica et al., 2001).

Previous studies have reported that the Under-10 age-group cover less distance at high-intensity running in 5v5 game format than 8v8, as well as the total distance covered by Under-13 age-group it´s lower in 8v8 game format than the 11v11 (Randers, Andersen, Rasmussen, Larsen, & Krustrup, 2014). However, Castellano, Puente, Echeazarra, and Casamichana (2015) suggest that the higher demands on player´s activity are more influenced by the increase of relative pitch area per player than by the decrease on the number of players per team.

From a technical and tactical perspective, Capranica et al. (2001) conducted a study with Under-11 age-group, suggesting advantages in 7v7 game format compared to the 11v11. Specifically, the authors demonstrated that in 7v7 format the total number of passes was higher and the total number of ball losses was lower compared to 11v11. On the other hand, a study with Under-8 and Under-10 age-groups suggested that there are no significant differences in the characteristics of the attack process during soccer matches performed in 7v7 and 8v8 game formats (Lapresa, Arana, Ugarte, & Garzón, 2009). Another study also compared the characteristics of the attack process during soccer matches performed in 9v9 and 11v11 game formats suggesting that 9v9 is a valuable alternative for the Under-10 and Under-12 age-groups, since 11v11 may reflect a structural constraint for young players to develop their activity proficiently (Lapresa, Arana, & Garzón, 2006). Finally, Lapresa, Arana, Anguera, and Garzón (2013) analysed the ball circulation patterns in soccer matches performed in 7v7, 9v9 and 11v11 game formats, demonstrating that the 7v7 and 9v9 formats promotes the development of game space management skills compared with 11v11.

Despite previous studies, there is still little scientific evidence about the changes produced on performance of players and teams due to the effect of structural and functional constraints in youth soccer competitions (Castagna, D'Ottavio, & Abt, 2003; Stroyer, Hansen, & Klausen, 2004), namely the pitch surface, game format and specific characteristics of the players. Therefore, it is difficult to justify whether soccer matches of youth competitions are being performed under game conditions adapted to the skill level and age of the players (Lapresa et al., 2009; Arana et al., 2004). These questions highlight the lack of an experimental framework that provides relevant information regarding the effect of the game constraints on performance of players and teams, making it challenging to undertake an objective analysis and evaluation of the players performance during soccer matches performed under the effect of the respective game constraints. Such limitations may compromise the development of pedagogical to improve the practice conditions and the development process of young players.

Performance analysis in soccer

Sports performance is one of the most complex areas of study as it is characterised by highly unpredictable human activity, such as the activity developed by humans during a soccer match (Cardinale, 2017). Since a soccer match expresses highly variable movements and behaviours, customized by the interactions between the players and the environment (Duarte, Silva, & Davids, 2015), soccer can be described as a dynamic and complex motor activity (Gréhaigne, Godbout, & Zerai, 2011). In this perspective, the complexity and the dynamic nature of the soccer match induce that observation and measurement become relevant to improve our understanding of the performance of the players and, in turn, of the teams (O´Donoghue, 2010). According to Gréhaigne et al. (1997) the players it exchanges energy, matter and useful information for maintaining its behavioural organisation during soccer match and, therefore, checking what comprises the performance and how players interact during a soccer match becomes essential to analyse performance in soccer (McLean, Salmon, Gorman, Read, & Solomon, 2017).

In the last decades we have witnessed a growth in the use of performance analysis in soccer context, namely in the development of performance analysis systems and in performance analysis research (Hughes & Franks, 2005; Lago, 2009). Performance analysis has been thought of as an academic discipline, a set of data collection tools and is concerned with investigating relevant aspects of performance of players and the teams in a sports environment, such as soccer (Drust, 2010; O'Donoghue, 2005). According to Carling, Williams, and Reilly (2005) may range in sophistication from discrete data about the activity of an individual player, or of each member of the team as an individual profile, to a synthesis of the interplay between individuals in conformity to a team plan. This research activity has been relevant to develop and promote a more reliable understanding upon specific performance indicators (Mackenzie & Cushion, 2013), which in turn contribute to describe the behaviour of the players during soccer matches (Carling, Wright, Nelson, & Bradley, 2014).

Performance analysis activity is also developed following pre-established routine stages that according O´Donoghue (2010) can be circumscribed as follows:

i. *First stage*: is data gathering, which can be done during or after a training session or soccer match;
ii. *Second stage*: is the analysis of the data, which can be done during competition where efficient systems can produce the result required within or immediately after competition;
iii. *Third stage*: is the communication of information to the relevant audience depending on the purpose and context.

In soccer match context, the performance of the players follows a set of previously defined rules that includes strategic and technical-tactical factors aiming, on the one hand, to develop adaptations to overcome the specific game constraints and, on the other hand, to reproduce high levels of performance to overcome the opponents, score goals and finally win the game (Bangsbo, 1994; Bradley et al., 2011; Brito et al., 2012). Since the performance in soccer depends on a set of factors, the data collection and respective analysis should consider the several indicators that affect players´ performance during the match. Consequently, performance analysis systems should be designed to collect data upon the most relevant aspects of performance, embracing, therefore, the technical, behavioural, physical and tactical indicators (Carling et al., 2005). In this framework, the main challenge for researchers is to clearly define what should be analysed and then to find the most efficient tools to complete the task.

Defining performance indicators

Performance indicators are a selection, or combination, of measurable action variables used to assess and monitor specific aspects of performance either of the players or the teams (O´Donoghue, 2010). In its turn, the players´ performance reflects the interaction of a myriad of technical, tactical, mental (Carling et al., 2005) and physical and physiological indicators (Drust, Atkinson,

& Reilly, 2007; Stølen, Chamari, Castagna, & Wisløff, 2005). With the purpose of circumscribing the main performance indicators Carling et al. (2005) proposed the following delimitation:

i. *Technical indicators*: identification of technical skills of the players, such as passing, shooting and heading;

ii. *Mental and/or Behavioural indicators: a*lthough mental factors cannot be assessed directly, they can be inferred from a player´s behaviour, such as ‘game-reading’ skill, decision-making, emotional state and concentration;

iii. *Physical indicators*: assessment of physical and physiological requirements of players, such as movement and work-rate;

iv. *Tactical indicators*: description of tactical behaviour of the players, such as movement and/or positioning of the players. From team perspective, identification and description of the game style adopted (for example, slow build-up versus a fast and counter-attack style of play).

According to Garganta, Maia, and Marques (1996) these indicators are described as those that more directly contribute to the expression of the performance of the players and teams in game environment. In this environment, match analysis can be designed to collect and interpret performance indicators aforementioned (Carling et al., 2005). Specifically, it is possible to quantify trends regarding the performance of players and teams, which in turn allows formulating reasonable explanations upon the object of analysis, i.e. soccer match (Carling et al., 2014). Thus, one of the main challenges for researchers is to find suitable tools to collect and analyse the several performance indicators in order to optimise the performance of the players and in turn of the teams (Aguiar, Gonçalves, Botelho, Lemmink, & Sampaio, 2015; Garganta, 2001).

Measuring performance indicators

There are a variety of methods that can be used to gather data on performance analysis indicators (O´Donoghue, 2010). However, the method to be used should take into account the characteristics of the study and the data set to be analysed (Carling et al., 2005).

Notational analysis is a valuable method for recording and analysing dynamic and complex situations that occur during soccer matches (Clemente et al., 2012; James, 2006). Traditionally focused on analysis of movement, statistical compilation and especially on technical and tactical evaluation (Hughes & Franks, 2004) it allows the data to be collected efficiently, providing an abstract view on the most important information (O´Donoghue, 2010). Specifically, this type of analysis is relevant to record the incidence and outcomes of the players´ actions (Hughes & Bartlett, 2002; Taylor, Mellalieu, James, & Shearer, 2008), which also contributed to optimise the feedback provided to the player and coach (Liebermann et al., 2002).

Concomitantly, new technological approaches, such as those based on video tracking and global positioning systems (GPS), has been contributing for new insights on the analysis of soccer players´ performance either in training session or game context (Cummins, Orr, O'Connor, & West, 2013; Gabbett & Mulvey, 2008). Portable GPS devices are equipped with sophisticated technology that allows to collect and/or tracking spatial-temporal data with reasonable accuracy, which are critical to better understand the performance of the players and in its turn of the teams (Cummins et al., 2013; Stølen et al., 2005). Specifically, this technology provides data related to the variability of movement, positioning, displacement and trajectories of the players in the pitch (Coutts & Duffield, 2010; Gray, Jenkins, Andrews, Taaffe, & Glover, 2010), which are critical aspects in the analysis of performance from a tactical point of view (Silva et al., 2014).

In this context, variability can claim several meanings. On one hand, it may reflect the versatility in the player´s performance (e.g. the amount of available skills for a specific task). Thus, the higher the technical skill of players, which in turn induces greater unpredictable in their movements, may reflect an increase of the variability. On the other hand, variability could also express the amount of tactical functions a player is expected to accomplish. Players and, ultimately, the team must be assumed behaviours that express the game concept designed by the coaching team. In this environment, if number of tasks to be performed by the players and/or their complexity is high can express behaviours of players and teams more unpredictable which in turn will reflect greater variability. In the previous cases, it can be considered that variability is under the control of the player and reflects its intentional actions. Furthermore, will also express the continuous effort of the players to adapt to unexpected events and specific game constraints (e.g. pitch surface, number of players, pitch dimensions, ball trajectories and displacements of teammates and opponents), which are most common in team sports.

Linear measures such as range, standard deviation and the coefficient of variation together with measures of central tendency (mean, median and mode) are being complemented with a non-linear measures such as the one based on entropy values obtained from player´s spatial distribution maps (Couceiro, Clemente, Martins, & Machado, 2014; Siegle et al., 2008; Silva et al., 2014; Silva et al., 2015) as well as relative positioning of the players in the pitch, centred on their average positional coordinates, with axes corresponding to the displacements´ standard deviations in the longitudinal and lateral directions of the soccer pitch, are contributing to provide relevant information upon the tactical behaviour of the players and teams (Silva et al., 2014; Yue, Broich, Seifriz, & Mester, 2008).

Through calculating the first and second derivative of the position with respect to time, analysing the speed and acceleration profiles of the players, is also a step forward to quantify player´s movements, the risk of loading and injury (Casamichana, Castellano, Calleja-Gonzalez, San Román, & Castagna, 2013; Varley & Aughey, 2013). Furthermore, spatial-temporal data allows to assess and control relevant physical indicators, such as total distance covered, speed and acceleration of the players during soccer match activity (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Gabbett & Mulvey, 2008). Therefore, the assessment and monitoring of such indicators becomes decisive so that coaches have reliable information and, consequently, to ensure a better understanding upon the players´ demands in competitive context (Gonçalves, Figueira, Maçãs, & Sampaio, 2014).

Synthetically, an academic and theoretical work can allow the integration of important contextual information (Carling et al., 2014). This information becomes relevant since the coaches and governmental bodies can know the actual conditions in which the soccer matches of youth leagues are being performed and, on the other hand to know if such game conditions influence the players´ performance. Thus, it becomes essential to broaden the research undertaken in the name of performance analysis from both a basic and an applied science perspective in order to impact practice (Mackenzie and Cushion (2013), which can contribute to apply the scientific knowledge in the design of sports practice conditions appropriate to the characteristics of young practitioners.

CHAPTER II

Structure of the thesis

Objectives

List of studies

Structure of the thesis

The present thesis is elaborated according to the norms and orientations of the Faculty of Sports of the University of Porto for the writing and presentation of dissertations and reports (FADEUP, 2009) and was divided into eight chapters. Chapter I contains a brief general introduction and highlights the problematic, state of the art and relevance of this investigation. In the chapter II it is exposed the structure of the thesis, the objectives and the list of studies. In the following three chapters (III, IV and V) five original studies are presented, conducted according to scientific guidelines of respective journals; the chapters/studies mentioned were submitted, accepted or published in peer-reviewed scientific journals. Chapter VI reports the general discussion while chapter VII highlights the main conclusions of the thesis, respectively. Finally, the Chapter VIII includes the references.

Table 2. Structure and content of the thesis

CHAPTER I	Introduction
CHAPTER II	Structure Objectives List of studies
CHAPTER III	Study 1. The game variants in Europe. Trends and perspectives during youth competitive stages.
CHAPTER IV	Study 2. Effects of pitch surface and playing position on external load activity profiles and technical demands of young soccer players in match play. Study 3. Effects of pitch surface on displacements of youth players during soccer match-play.
CHAPTER V	Study 4. Match-running performance of U8 to U14 soccer players during 5v5, 7v7, 9v9, and 11v11 soccer match-play. Study 5. The influence of the 5v5, 7v7, 9v9 and 11v11 game

Objectives

The general objective of this thesis is to provide pedagogical guidelines for the effective modelling of formal soccer match context to the young player´s characteristics, investigating for such purpose whether functional and structural constraints promote asymmetries in physical, technical and tactical performance of the players. With the purpose to accomplishing the general objective, five specific objectives were established, which in turn resulted in five original studies:

1. To examine how European countries, manage the type of game formats used in youth championships and correlate them to the age of players.
2. To analyse the effect of pitch surface on running activity and technical performance of young soccer players.
3. To inquire the effect of pitch surface on variability of positioning and displacement of young soccer players during match play.
4. To investigate the effect of game format and age-group on match-running activity variables of young soccer players.
5. To explore the influence of the 5v5, 7v7, 9v9 and 11v11 game formats on the positioning and displacement of young soccer players during match-play.

List of studies

This thesis encompasses a collection of five original research articles with indication of published or submitted in peer review journals (Table 2). The articles follow a sequential and coherent logic of work and are ordered with the general and specific objectives of thesis.

Table 3. Original scientific articles

Study I

Brito, A., Duarte, R., Diniz, A., Maia, J., & Garganta, J. (2017). The game variants in Europe. Trends and perspectives during youth competitive stages. *Motriz: Revista de Educação Física, 23*(3), e101753.

Published

Study II

Brito, A., Roriz, P., Silva, P., Duarte, R., & Garganta, J. (2017). Effects of pitch surface and playing position on external load activity profiles and technical demands of young soccer players in match play. *International Journal of Performance Analysis in Sport, 17(*6*), 902-918.*

Published

Study III

Brito, A., Roriz, P., Silva, P., Duarte, R., & Garganta, J. (2018). Effects of pitch surface on displacements of youth players during soccer match-play. *Journal of Human Kinetics*. DOI: 10.2478/hukin-2018-0046.

In press

Study IV

Brito, A., Roriz, P., Duarte, R., & Garganta, J. (2018). Match-running performance of young soccer players in different game formats. *International Journal of Performance Analysis in Sport. 18(*3*), 410-422.*

Published

Study V

Brito, A., & Garganta, J. (2018). The influence of the 5v5, 7v7, 9v9 and 11v11 game formats on the positioning and displacement of young soccer players during match-play. *Journal of Human Kinetics.*

Submited

CHAPTER III

Study I.

Published

Brito, A., Maia, J., Garganta, J., Duarte, R., & Diniz, A. (2017). The game variants in Europe. Trends and perspectives during youth competitive stages. *Motriz: Revista de Educação Física*, *23*(3), e101753. doi.org/10.1590/s1980-6574201700030023

The game variants in Europe. Trends and perspectives during youth competitive stages

Abstract

Aims: The aim of this study was to verify how European countries manage the type of game formats variants and their frequency along youth competitive stages. **Methods:** Data were collected from the official rules of youth football championships. To identify countries homogeneous groups according to their game variants, Two Step Cluster Analysis procedure was used while a nonparametric Kruskal-Wallis test was used to compare the game variants distribution in each Cluster. To correlate the game variants with age groups, a Chi-Square independence test and a Spearman ordinal correlation coefficient were used. **Results:** The results showed there were five clusters with significant differences in their game variants distribution ($X^2_{kw}{}^{(4)} = 22.149$; $p < 0.001$; $n = 30$) and a significant correlation between age group and game variant ($\chi^{2(63)} = 477.724$; $p < 0.001$; $n = 30$). Specifically, the most used game variants in each age group were the five-a-side (F5) in Under-8; the nine-a-side (F9) in Under-12; the seven-a-side (F7) in Under-9 and Under10; and the eleven-a-side (F11) in and above Under-13. **Conclusion:** These results may contribute to understand the different country perspectives about the competitive game variants of youth football within the European space and its relationship with diverse learning philosophies and pathways.

Keyword: youth soccer, game variants, team sport, development pathways, association football

Introduction

Football is a cultural phenomenon of high impact on a global scale. This phenomenon has enhanced the attractiveness of the sport as a professional occupation for performers at the highest level, where the financial rewards for success are considerable[1]. Thus, it is not surprising that the development of youths into expert or professional soccer players in adulthood is being the goal of professional clubs and national governing bodies[2]. Moreover, most soccer academies are seeking to optimise the development of their young players and helping them acquire the skills necessary to perform successfully in formal competition along their developmental pathway[3]. This pathway can last for 14 years before the child achieve adulthood[4] and along mentioned period a significant investment of practice time and effort is required to reach an elite level of performance[5]. In this context, the practice conditions may be a decisive factor to long-term success in soccer[1], where the game variants used in the formal soccer matches can assume a determinant role during formative years of the players.

In previous decade, the Union of European Football Associations (UEFA) increased the pressures so that each Association member (i.e. each country) to organize soccer matches adapted to the physical, cognitive, and maturational level of young players with purpose to provide them adjusted developmental conditions[6]. Despite these pressures, it is still recurring to find young players competing in game conditions unsuitable to skill level and age of the players, in particular the 11-a-side soccer game[7]. Therefore, an important question to consider is whether the 11-a-side game variant should be used in the early stages of the young players´ learning process[8,9]. Previous studies suggested that soccer matches played in variants with these characteristics, limit the number of contacts the players have with the ball[10,11] as well as improve tactical complexity by increasing the variability of actions and the possibilities of play[12]. In addition, Capranica, Tessitore[13] suggested that there are advantages in 7-a-side game variant compared to 11-a-side for players of 11 years old. These authors concluded the 7-a-side variant induces an increase in the number of passes and a decrease in the number of ball losses, compared to the 11-a-side. Another study by Lapresa, Arana[14] analysed the ball circulation patterns in 7-a-side, 9-a-side, and 11-a-side variants, concluding the 7-a-side and 9-a-side promotes the development of game space management skills, compared to the 11-a-side. Recently, Randers, Andersen[15] suggested that playing with fewer players on smaller pitches results in minor changes to the physical loading but increases technical involvement (stimulus) of players. In general, it can be considered that determined game conditions can constraint the skills improvement of the players along their developmental process[16]. Accordingly, the aforementioned studies highlighted the need to adapt the game variant to the players´ capabilities, to provide the appropriate conditions to their technical and tactical development.

Despite there has been progress in our understanding of the types of practice activities that best develop expert athletes[5,17], to the best of our knowledge, there is no scientific information about the type of game variants used by European countries across the different age groups. This information can reveal how the different European Football Associations conceive and adapt the game structure to the performance level of young players along their developmental pathway. On the other hand, it can contribute to base youth development policies and practices upon scientific evidence[3,5].

In this sense, this study aims: (1) to verify the type of game variants and their frequency across the different age groups of youth football competitions implemented by the European national Football Associations; (2) to examine whether there is some relationship between the game variant used and the respective age group. We hypothesized a significant relationship between age group and game variant used by European countries along their developmental pathways.

Methods

Sample

Thirty European countries (See Table 1), which correspond to fifty-six percent of the UEFA members[18], were used as sample. The member countries were selected according to the following criteria: (1) world *ranking* of *Fédération Internationale de Football Association* - (FIFA) for national teams - this *ranking*, is a system that allows to classify all national football teams from 1st to 209th, based on the results of matches[19]; (2) *ranking* of the UEFA coefficients - the UEFA coefficients are statistics used to classify the clubs of each European country from 1st to 454th, which participate in international competitions, such as the *Champions League* and *Europe League*. This classification is assigned based on the results obtained by each team who participated in matches played in European competitions over the last five years and aims to define the teams that will participate in the European competitions of the following year[20].

Table 1. Frequency and type of game variants used by UEFA member countries per European region during youth competition stages

European regions	Countries	Number of game variants used	Game variants used							
			F3	F4	F5	F6	F7	F8	F9	F11
Western Europe	Germany	3					×		×	×
	Austria	4			×		×		×	×
	Belgium	3			×			×		×
	Scotland	4		×	×		×			×
	France	4			×		×		×	×
	Netherlands	4		×			×		×	×
	England	4			×		×		×	×
	Northern Ireland	4			×		×		×	×
	Republic Ireland	5	×		×		×		×	×
	Switzerland	5		×	×		×		×	×
	Frequency		**10%**	**30%**	**80%**		**90%**	**10%**	**80%**	**100%**
Northern Europe	Denmark	4	×		×			×		×
	Finland	5		×	×		×		×	×
	Norway	5	×		×		×		×	×
	Sweden	5	×		×		×		×	×
	Frequency		**75%**	**25%**	**100%**		**75%**	**25%**	**75%**	**100%**
Central Eastern Europe	Bulgaria	4			x		x		x	x
	Croatia	2							x	x
	Slovakia	3				x		x		x
	Slovenia	2					×			×
	Poland	3				×		×		×
	Hungary	4		×			×		×	×
	Czech Republic	4			×	×		×		×
	Romania	2						×		×
	Russia	7	×		×	×	×	×	×	×
	Serbia	7	×	×	×	×	×	×		×
	Ukraine	4	×		×		×			×
	Frequency		**27%**	**18%**	**45%**	**45%**	**54%**	**54%**	**36%**	**100%**
Southern Europe	Spain	3					×	×		×
	Greece	2							×	×
	Italy	5			×	×	×		×	×
	Portugal	2					×			×
	Turkey	5				×	×	×	×	×
	Frequency				**17%**	**40%**	**80%**	**40%**	**60%**	**100%**
	Total of game variants used		**7**	**6**	**18**	**7**	**22**	**10**	**18**	**30**

Note: Game variants description: F3 = three-a-side; F4 = four-a-side; F5 = five-a-side; F6 = six-a-side; F7 = seven-a-side; F8 = eight-a-side; F9 = nine-a-side; F11 = eleven-a-side.

The member countries that did not participate in the study were excluded according to the following criteria: (1) ranked below the fifty percent in the International Football Federation (FIFA) world ranking; (2) ranked below the fifty percent in the UEFA coefficients *ranking*; (3) without information about the used game variants during youth competitions. Using these criteria, we obtained a sample of the 30 more representative European countries/Football Associations in terms of European football. The study followed the guidelines stated in the Declaration of Helsinki and was approved by the local Ethics Committee.

Data collection procedures

The information about the game variants used in the European countries was obtained according to a *flow diagram* (Figure 1), adapted from PRISMA protocol[21] used in systematic reviews.

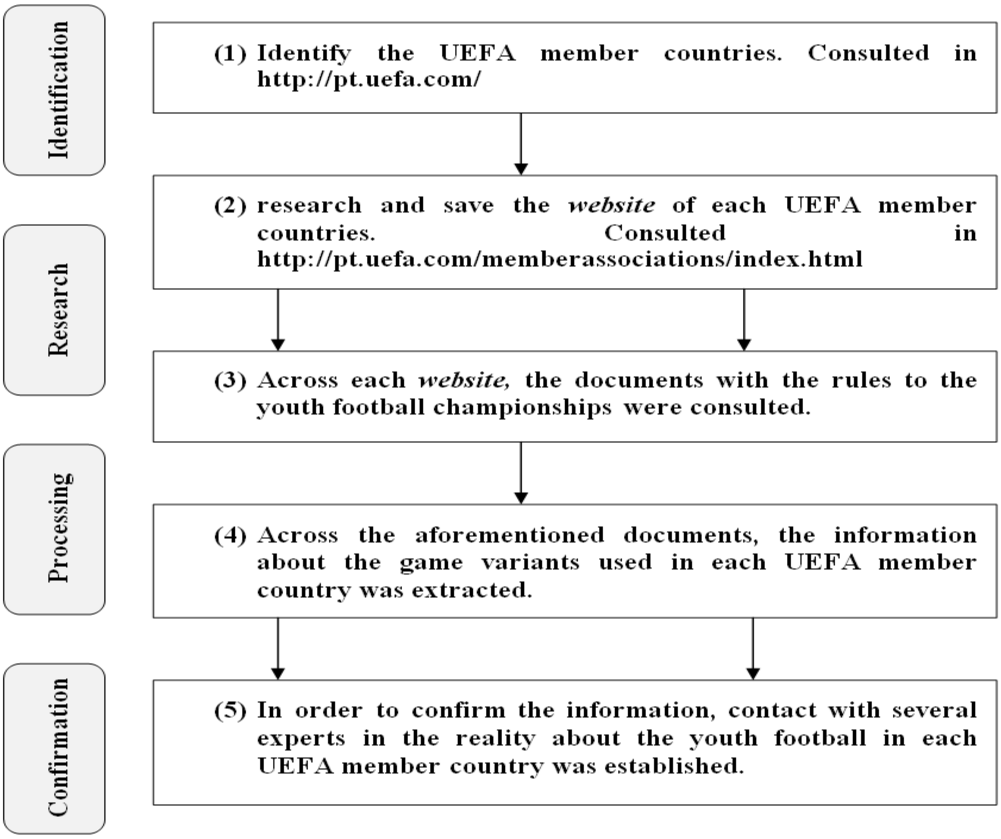

Figure 1: Diagram concerning to data collection.

Statistical Procedures

Descriptive analyses were carried out to quantify the frequency of game variants used. A Two Step Cluster Analysis procedure was performed to identify homogeneous (groups or *clusters*) of member countries according to the type of the game variants used. An exclusion criterion was defined, consisting in removing the game variants with relative frequencies smaller than 0.15, to improve the overall model quality. A Correspondence Analysis was performed with symmetrical normalization in a two-dimensional axis system, representing the countries in respective Clusters. Then, a nonparametric Kruskal-Wallis test was performed to compare the distribution of game variants in each Cluster. Finally, a Chi-Square test of independence and an ordinal correlation coefficient of Spearman were used to correlate the age group with the game variants used. All statistical analyses were performed using SPSS Statistics, version 22.0 (SPSS Inc., Chicago, USA). For all analyses, statistical significance was set at $P < 0.05$.

Results

Concerning the frequency of game variants, there was a clear predominance of game variants involving an odd number of players, such as the 11-a-side (F11) variant (see Figure 2). More precisely, the game variants with higher expression in the Europe are the 11-a-side, 7-a-side (F7), 5-a-side (F5), and 9-a-side (F9) respectively, presenting relative frequencies above 50%.

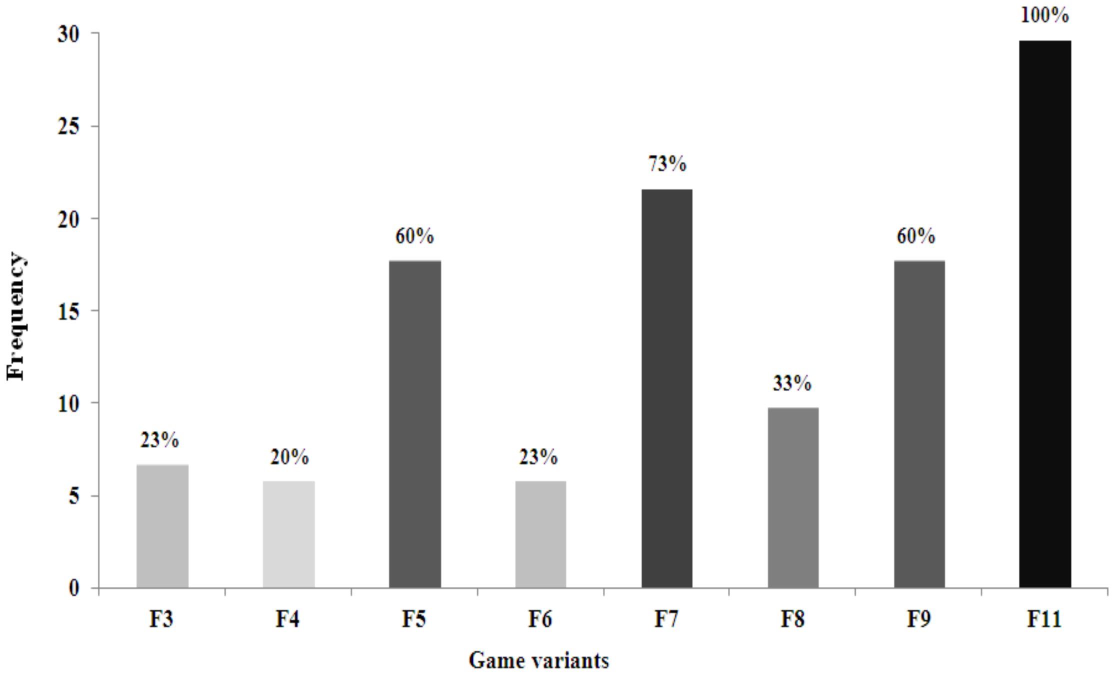

Figure 2: Overall frequency (%) of game variants used in UEFA member countries
Note: F3 = 3-a-side variant; F4 = 4-a-side variant; (......); F11 = 11-a-side variant

As shown in Table 2, five different clusters were created, with an adjustment measure of cohesion and separation of "Good". Largest cluster - cluster three - comprises eight (26.7%) of the UEFA member countries, while the smallest - cluster one – combines four (13.3%). Concerning the clusters´ profiles, cluster one contains the F7 and F11 game variants; cluster two the F7, F9, and F11; cluster three the F5, F7, F9, and F11; cluster four the F11; and cluster five the F5 and F11 game variants. The F7 game variant has a predictor importance of 0.80, the F5 an importance of 0.88, and the F9 an importance of 1.00.

Table 2. Cluster Distribution.

		N	% of Total	Variants
Cluster	1	4	13.3%	F7, F11
	2	6	20.0%	F7, F9, F11
	3	8	26.7%	F5, F7, F9, F11
	4	7	23.3%	F11
	5	5	16.7%	F5, F11
Total		30		100,0%

In addition, the Correspondence Analysis provided a clear view of the countries distribution in each of the five clusters (Figure 3). For instance, cluster one associated to the F7 and F11 game variants includes Portugal, Spain, France, and Slovenia, while cluster five linked to the F5 and F11 variants incorporates Belgium, Switzerland, Scotland, Serbia, and Denmark. The Kruskal-Wallis test showed there are significant differences in the distribution of game variants used in each cluster ($X^2_{kw}{}^{(4)} = 22.149$; $p < 0.001$; $n = 30$).

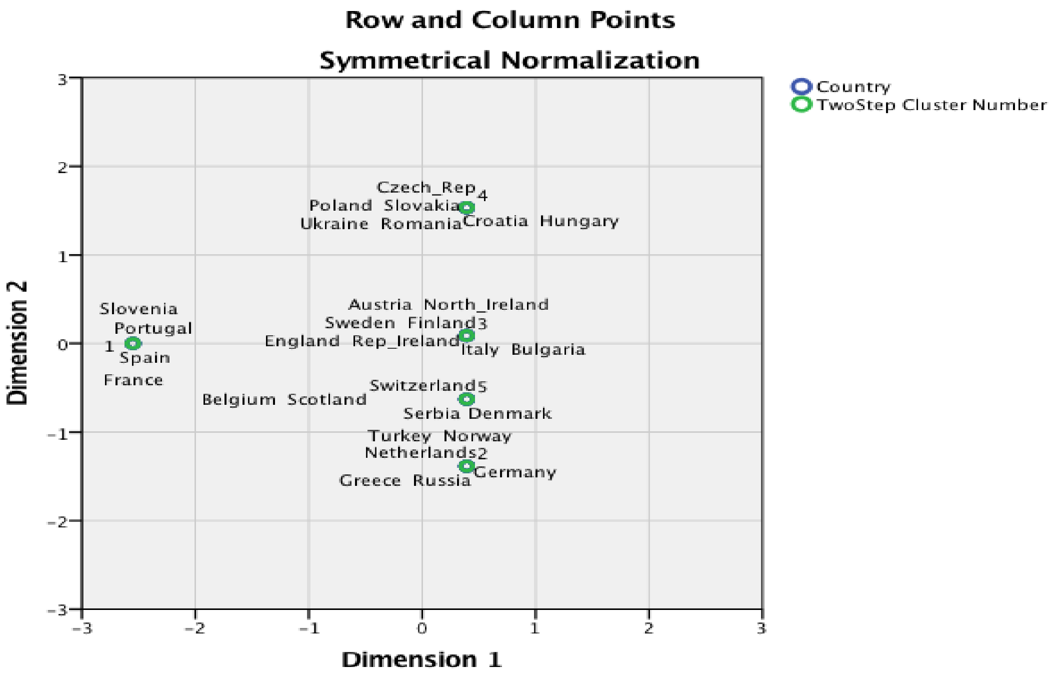

Figure 3: Countries representation in each Cluster using Correspondence Analysis.

Table 3 displays the relationship between game variant versus age group. The Chi-Square test yielded a significant correlation between age group and game variant ($\chi^2(63) = 477.724$; $p < 0.001$; $n = 30$), with a Spearman correlation coefficient of 0.852. More precisely, there is a trend toward an increase in the players´ number along the different age groups of youth competition (i.e., the increase of the players´ age is associated to the increase the number of players and overall space of the game variants).

Table 3. Frequency of the game variants used across the different age groups of the youth competitions.

		Game Variants							
		F3	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F11**
Age-group	**U-5**	10%	3,3%						
	U-6	20%	10%	20%	3,3%	3,3%		3,3%	
	U-7	6,7%	16,7%	46,7%	6,7%	6,7%	3,3%	3,3%	
	U-8		3,3%	50%	10%	30%	6,7%	6,7%	
	U-9			16,7%	13,3%	56,7%	10%	6,7%	
	U-10			3,3%	10%	63,3%	16,7%	10%	
	U-11				10%	46,7%	20%	33,3%	3,3%
	U-12					23,3%	23,3%	53,3%	20%
	U-13					6,7%	13,3%	16,7%	73,3%
	U-14								100%

Note: Game variants description: F3 = three-a-side; F4 = four-a-side; F5 = five-a-side; F6 = six-a-side; F7 = seven-a-side; F8 = eight-a-side; F9 = nine-a-side; F11 = eleven-a-side.

Despite the predominant use in Under-7 and Under-8, the F5 game variant is only present in five age groups. On the other hand, the F7 and F9 are the most used game variants until Under-14. Specifically, the F7 shows greatest expression in Under-10, while the F9 predominates in Under-12. The F11, until the Under-14, is present in four age groups. However, the use of this game variant is more frequent in and above the age of 13.

Discussion

The aim of the present study was to examine how the European countries conceive and implement the different game variants along the youth developmental pathway toward the 11v11 variant. Our results showed that in Europe the type and frequency of game variants used vary progressively along youth competition stages (age). Most of countries (sixty percent) privilege the progressive use of four or five game variants, which denotes some care to adjust the game variants to the most appropriate youth competition stage[8]. Interestingly, the FIFA and UEFA ranking does not reveal indicators that these eighteen countries are in the best positions when compared with others. We argue that presumably these countries prescribe conditions of sport practice with a "formative guidelines" (i.e. the focus is to develop the physical and motor skills of young athletes) instead of a "result orientation" (i.e. achieving results is more important than players development). From learning viewpoint these variable practice conditions can be advisable to develop a more effective learning, contributing decisively to the players´ developmental[5]. Therefore, it can be hypothesized that these eighteen countries demonstrate a high degree of pedagogical concern in structuring progressively the process of learning soccer. This may suggest the learning process established on these eighteen countries is the most effective, as previous literature indicated[8].

On the other hand, the results revealed that ten countries only use two or three game variants, which can compromise the development of fundamental technical and tactical skills such as the relation with the ball and game space management[14]. Therefore, it is symptomatic that in countries such as Croatia, Slovenia, Romania, Greece and Portugal, the type of game variants used and their respective frequency across different age groups seems to suggest a maladjustment to the needs and characteristics of young soccer players[6,7], as well as to the transfer of learning from small to more complex game variants. Consequently, we can hypothesise the youth football policies of the mentioned countries are neglecting the importance that the game formal structure can assume in the soccer players´ learning process. The cultural influences and national governing bodies of each country may explain the options taken in the respective process[16], which suggests that the nature of the formal soccer activities of competition engaged in during childhood seems to be dependent on the country and its respective youth development system[2]. Therefore, the challenge for coaches and national governing bodies is to find how best to recreate match-play conditions as well as ensuring that the game requirements are appropriate relative to the age and characteristics of the young soccer player[3]. In this perspective, it would be advisable to carry out some modifications in the competition rules to adjust the formal game structure to the players´ characteristics, rather than forcing them to play in inappropriate game environments to their age level. According these latter positions, it is suggested that the description of the youth development systems and pathways that players engage during competition soccer games may contribute to identifying what factors may require change, as previously reported by Ford, Carling[2].

Another interesting finding of our study is that the most used game variants involve an odd number of players. Since we are not aware of comparable data in the literature that have addressed the issue of the main game variants in Europe to use an odd number of players, we assume that the cultural factor can induce this trend, reflected in the expressive use of 11-a-side. In the history of football, whose rules of 1863 are still the basis of this sport currently, it was defined that this game was played between two teams and that each team had 11 players. Another potential reason, it may be due to the influence of the 3-a-side game variant (also odd number) which is the variant recommended in the first stage of developmental process of the players. Finally, it may result from a logical principle with the purpose to standardizing the rules of youth competition in the European countries.

Our results also pointed out the three-a-side game variant presents higher expression in Under-6, the five-a-side is the most frequent in Under-8, the seven-a-side reveals the highest use in Under-10, and the nine-a-side emerges as the most selected game variant in Under-12. Moreover, in and above the Under-13, the eleven-a-side is the most used game variant, which is in accordance with previous studies[4]. From the pedagogical point of view, this pattern seems balanced, since can contribute to improve the player´s technique and fitness[10] as well as sustain that t transition to the next stage is supported by an appropriate enlargement of the number of players and the overall available space of the corresponding competitive game variant[8]. Furthermore, this incremental strategy permits to preserve a greater involvement in the game which stimulates individual technical and tactical abilities, increase the players´ motion[15] and, thus, enhances the overall learning experience of young players.

In relative terms, it can be hypothesised the game variants with lowest number of players as well as smaller dimensions are more suitable for children, especially in early stages of their developmental. As suggested by Clemente, Wong[12,13], such hypothesis might be attributed to a higher individual participation, as the increasing of the time individual players are in possession of the ball, contributes decisively to their development of the tactical and technical skills. Since the dimensions of the variant can influence the development of tactical and technical skills, we argued that decision-making bodies of the UEFA or FIFA should define the size of the fields for all variants of the game, which unfortunately does not happen. The International Football Association (FIFA) only recommends official dimensions for 11-a-side and 5-a-side soccer pitches. Despite this recommendation, it is still possible to identify differences between the maximum dimensions (90m x 120m) and minimum dimensions (45m x 90m) of pitch size recommended to the 11-a-side game. For 5-a-side game, FIFA establishes a minimum of 18m x 38m up to maximum 25m x 42m. Regarding other football pitch sizes, FIFA has not published any official dimensions. Therefore, we suggest that the pitch size must be defined using proportionate and standardized measures to enable a comfortable and adequate game to the player´s requirements.

Future analytical research should examine the technical and tactical impact of a step-by-step incremental strategy compared to the use of few game variants along the players´ developmental pathway. This kind of information is vital to improve the knowledge about the official game variants implemented within the UEFA region, which seems relevant to support adequate players´ long-term development programs.

Conclusion

The current findings confirm that there is a trend in the type and frequency of the game variants used by European countries toward a progressive increase of the game area and players´ number along the developmental pathway. The most commonly used game variants on each age group (with relative frequencies greater than or equal to 50%) are the 5-a-side in Under-8; the 7-a-side in Under-9 and Under-10; the 9-a-side in Under-12; and the 11-a-side in and above Under-13, respectively. However, the statistical analyses showed there are significant differences in the used game variants across the different countries. It was shown that 33% of the countries use between two to three game variants, while 60% use between four to five variants. However, according to the literature[8], the progressive use of four or five game variants seems to deliver a more effective long-term development of the players´ attributes. Thus, the challenge football organizations (e.g. UEFA) face is to determine whether there is an advantage to create a standard learning pathway, specifying which game variants must be used in each age group toward the 11v11 variant. According to Newbery[4], this is no small task, but it is essential for football organisations seeking to raise coaching and playing standards.

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CHAPTER IV

Study II.

Published

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Effects of pitch surface on external load activity profiles and technical demands of young soccer players in match play

Abstract

This study aims to analyse the effect of different pitch surface, i.e. artificial turf (AT), natural turf (NT) and dirt field (DF) on running activity and technical demands of young soccer players (age: 13.4 ± 0.5yrs; height: 161.82 ± 7.52cm; body mass; 50.79 ± 7.22kg and playing experience: 3.5 ± 1.4 yrs). Running activity data were collected using GPS units which allowed the calculation time–motion variables. Technical performance data were registered filming soccer matches. Analysis of variance (ANOVA) with repeated measures was employed to assess differences among variables. Total distance covered; distance for low-intensity running and very high-intensity running were higher on AT than NT (TD: $\eta^2 = .09$, $p = .007$); (LIR: $\eta^2 = .062$, $p \leq .05$); and (VHIR: $\eta^2 = .05$, $p \leq .05$), respectively. Significant differences were identified between pitch surfaces on successful passing ($\eta^2 = .052$, $p = .051$); unsuccessful passing ($\eta^2 = .155$, $p < .001$); and interceptions ($\eta^2 = .1087$, $p < .001$). Results suggest that pitch surface influences running activity and technical actions of young players. This information contributes to understand the different demands imposed in each pitch surface and, provides to the coaches the opportunity to implement strategies that could optimise players' performance.

Keywords: Assessment; time–motion; performance analysis; technical demands; team sport

Introduction

Performance profiles of soccer players provide a collection of relevant information about sport performance (Butterworth, O'Donoghue, & Cropley, 2013). Therefore, the assessment of the young soccer players´ performance profiles can be determinant to implement long-term training intervention strategies and, also contribute to improve the talent detection procedures (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Liu, Gomez, Gonçalves, & Sampaio, 2016). Despite performance could depend on a myriad of factors (Stolen, Chamari, Castagna, & Wisloff, 2005), according to Impellizzeri and Marcora (2009), the physical, technical and tactical indicators are probably the most relevant in the analysis of the players performance either in training or game. In fact, the available research has been focused on the analysis of physical and physiological indicators (Casamichana & Castellano, 2010; Castellano, Puente, Echeazarra, Usabiaga, & Casamichana, 2016) and technical and tactical indicators (Clemente, Couceiro, Martins, & Mendes, 2012; Praça, Soares, Matias, Costa, & Greco, 2015). Nevertheless, the pitch surface could influence the expression of the above indicators and little is known about that. Thus, it seems relevant to evaluate the effect of pitch surface and playing position on physical, tactical and technical demands, considering for this purpose the different soccer match conditions (Buchheit et al., 2010; Dellal et al., 2012; Mohr, Krustrup, & Bangsbo, 2003).

Notational analysis is a valuable tool to analyse technical performance indicators, such as the prevalent technical actions during a match (Clemente et al., 2012; James, 2006). In addition, a new set of technologies, such as those based on video tracking and global positioning systems (GPS), has been contributing for new insights on the analysis of soccer players´ performance either in training or game (Cummins, Orr, O'Connor, & West, 2013; Gabbett & Mulvey, 2008). Portable GPS devices provide spatial-temporal data with the reasonable accuracy that enables to analyse the covered distance, speed and acceleration which are an indicator of the physical demands (Buchheit et al., 2010; Gabbett & Mulvey, 2008), contributing to a better understanding of the players performance as well as the soccer matches requirements (Gonçalves, Figueira, Maças, & Sampaio, 2014). Moreover, the possibility of gathering time data along with the positional data, using relatively high acquisition frequencies (e.g. 10 Hz), also contributes to calculate the first and second derivatives of position with respect to time, i.e. the analysis of player´s velocity and acceleration profiles, a step forward in the analysis of the quality of player´s motion, load and injury risks (Casamichana, Castellano, Calleja-Gonzalez, San Roman, & Castagna, 2013; Varley & Aughey, 2013). That´s why this technology can be employed to analyse spatial-temporal data of the players during soccer matches, revealing the distribution of their efforts into categories according to speed thresholds (Goto, Morris, & Nevill, 2015).

Although many studies have analysed the players´ efforts into categories according to speed thresholds during elite soccer matches (i.e. national competition level or professional) either on adults (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Bradley et al., 2009) or young´s (Buchheit et al., 2010; Castagna, D'Ottavio, & Abt, 2003; Goto et al., 2015) there is a paucity of data examining the activity profile exhibited by non-elite young players (i.e. local competition level) during actual match-play (Rebelo, Brito, Seabra, Oliveira, & Krustrup, 2014). In this context, previous studies have suggested differences in running activity related to the level, age-group and tactical positioning of soccer players. For instance, a study with adult professional soccer players suggested that participants cover a distance of ~11,000 m per 11-a-side soccer match, of which 25% was covered by high-intensity running, 9% by very high-intensity running and the vast majority at low intensity (Bradley et al., 2010). Considering youth participants, a study by (Goto et al., 2015) examined the distances and speeds covered during 11-a-side match play for U11–U16 English Premier League Academy players and concluded that elite youth players covered a distance of ~5800 m for the U11 to ~7700 m for the U15 (~33%), of which 10–12% was covered by high-intensity running (speed from 13.1 to 16 km.h−1), and 5–7% was covered by very high-intensity running (speed from 16.1 to 19 km.h−1). In addition, Rebelo et al. (2014) demonstrated that the average distance covered by U-17 non-elite soccer players per 11-a-side match was ~6000 m, of which 12% on high-intensity activities (757 m) and the average speed was 4.8 ±.4 kmh−1 (ranging from 3.8 kmh−1 to 5.0 kmh−1). With regard to the tactical positioning of the players, previous studies performed with adult (>18) and young players (13–18 years old) demonstrated that the central defenders tending to cover less distance compared with all other positions; the central midfielders, fullbacks and central defenders covered a lowest distance on high-intensity running; and the wide midfielders and forwards covered a greater distance on very high-intensity running activity (Bradley et al., 2009; Buchheit et al., 2010).

In terms of the technical performance, recent data suggested that the player´s technical versatility or availability can be affected by the unexpected events and specific game constraints, such as the team characteristics, opponent´s opposition level, match location, standard of competition and match outcome (Liu et al., 2016; Mackenzie & Cushion, 2013). For instance, Owen, Wong, McKenna, and Dellal (2011) investigated the difference in technical activities placed upon European adult professional players when exposed to three-a-side vs. nine-a-side soccer matches and concluded that three-a-side game induced a higher number of dribbles, shots, and tackles than the nine-a-side. Another study by Bradley et al. (2011) examined the effect of playing formation on technical performance during professional soccer matches of English FA Premier League and suggested that the fraction of successful passes was highest in a 4–4–2 compared with 4–3–3 and 4–5–1 formations. Furthermore, it has been compared the technical skills of under-19 soccer players by competitive level (elite vs. non-elite) and playing position (goalkeeper, central defender, fullback, midfield, forward) and differences between elite and non-elite goalkeepers for ball control and elite central defenders performed better than their non-elite counterparts in ball control tests were found (Rebelo et al., 2013).

Despite the importance of these studies, performed in natural turf or artificial turf, few studies have considered assessing the players´ performance during soccer matches under the constraint of the pitch surface. A recent research by (Santos, Dias, Garganta, & Costa, 2013) to compare the tactical performance of young U13 soccer players on three distinct pitch surfaces i.e. artificial grass, natural grass and dirt field with an area of (length: 36 m, width: 27

m) concluded that the pitch surface do not influence the players´ tactical performance. Other study has examined the movement patterns, ball skills, and the impressions of adult professional players during competitive games on artificial turf and natural grass and demonstrated that the running activities and technical standards were similar during games on artificial turf and natural grass (Andersson, Ekblom, & Krustrup, 2008). However, a study by (Folgado, Duarte, Laranjo, Sampaio, & Fernandes, 2007) aimed to identify technical responses to variation on pitch dimension (30,620 m; 20,615 m) and surface (grass; sand) in “3-a-side” drills performed by U10 youth players, showed that the number of successful passing was higher in the natural turf compared to the sand. Additionally, with adult professional participants, it has also been shown that the ball possession and number of passes increased 20% during competitive games performed in artificial turf compared to natural turf (Andersson et al., 2008). On a physical and physiological perspective, Brito, Krustrup, and Rebelo (2012) reported that there are differences between the surfaces on the running speeds, heart rate, blood lactate levels and perceived exertion of adult non-elite players during five-a-side soccer games under three surface conditions (sand, artificial turf and asphalt). Finally, Binnie et al. (2014) investigated the training benefits of sand surface vs. grass throughout an eight-week conditioning programme in well-trained adult female and concluded that using sand surfaces in a team sport pre-season training programme may allow for more optimal athlete preparation, by maximising the training response and reducing performance-limiting effects that may arise from heavy training loads on firm surfaces.

Although previous studies have contributed to improving the scientific knowledge upon the players´ performance in specific match conditions has not yet been investigated how the three pitch surfaces usually most used during actual match play (i.e. artificial turf; natural turf; and dirt field) influences the running activity and technical actions of young non-elite players. Moreover, it seems relevant to determine the effect of the playing position on the running activity and technical actions on each pitch surface. In this sense, this insight may provide additional information about the specific requirements that each surface induces, a prerequisite for coaches to improve the physical and technical ability of the soccer players along their developmental pathway. Therefore, this study aims (1) to investigate the effect of pitch surface on running activity profiles of young soccer players; (2) to identify the effect of pitch surface on the type of technical actions performed; (3) to determine whether there are differences on running activity and technical actions between playing positions. It is hypothesised that the three pitch conditions elicit different technical and physical demands.

Methods

Participants

Sixty-six male U-14 soccer players, organised into 3 teams of 22 participated in the study (age: 13.4 ± .5 years; height: 161.82 ±7.52 cm; body mass; 50.79 ±7.22 kg). All players compete at a regional-level exhibiting a match and training experience of 3.5 ± 1.4 years. The U-14 age-group was chosen because 40% of soccer matches are still played on dirt field, at the regional championship U-14 (AF Porto, Portugal). The participants (teams and players) selection was conducted in accordance with the following criteria: (1) teams and players registered at the Porto Football Association championship; (2) teams and players from the same competitive level. All players and their tutors were informed about the research procedures, requirements, benefits and risks, and their written consent was obtained before the study began. The study protocol followed the guidelines stated in the Declaration of Helsinki and was approved by the local Ethics Committee.

Experimental design

During three weeks, always on Sundays, a total of nine matches were performed and analysed (three soccer matches per surface condition at each week). The teams and players who participated in the study were always the same and all matches were played in 1-4-3-3 tactical structure, the most used in

Portugal by youth teams (Rebelo et al., 2014). The playing positions were classified according to the players´ tactical function: (1) central defenders (DC, *n* = 12); (2) centre forwards (CF, *n* = 6); (3) central midfielders (CM, *n* = 18); (4) wide midfielders (WM, *n* = 12); (5) fullbacks (FB, *n* = 12). The goalkeepers participated in the matches but were excluded from the analysis. The matches were played with the soccer rules, except player changes (were not allowed) and matches duration. Although the games in the U14 championship have an official duration of 35 × 2 min, we decided to use 30 min without breaks to reduce the fatigue effect. The pitch size was adjusted to standardise the measure for all conditions (length: 100 m, width: 64 m). Six extra soccer balls were always available near the goalposts and on the side of the pitch for prompt replacement when the ball left the playing area. All matches were proceeded by a planned, standardised warm up of 15 min comprising running activities, small-sided games and stretching. Following this period, the players simulated a match during two periods of 2 min, interspersed by 1 min of passive recovery. All games were played between 9 and 11 am, under similar climatic conditions. This protocol was previously sent to the teams. The players were previously informed about the procedures they should adopt.

Data collection

Each player carried a global positioning tracking device (Qstarz, Model: BT-Q1000eX) that recorded his 2D positional coordinates at a sampling frequency rate of 10 Hz (Johnston, Watsford, Pine, Spurrs, & Sporri, 2013). The GPS was placed on the upper back of the player (using an appropriate harness). The pitch surfaces were calibrated with the coordinates of four GPS devices stationed in each corner of the pitch for approximately 4 min. The absolute coordinates of each corner were calculated as the median of the recorded time series, providing robust measurements to typical fluctuations of the GPS signals. These absolute positions were also used to define the reference Cartesian coordinate systems for each pitch, with its origin placed at the pitch centre. GPS Longitudinal and latitudinal (spherical) coordinates were converted into Cartesian coordinates with the Haversine formula (Sinnott, 1984). Fluctuations in players positions were reduced using a moving average filter with a time scale of (.2s) and data resampling was employed to synchronise the time series of all players within each soccer matches (Silva et al., 2015). The matches were recorded with a digital camera (Sony Handycam DCR-SR210) that was used to record and save the technical actions. The camera was fixed on a tripod (Sony VCT-R6400) placed at the pitch centre, with an elevation of 6 and 20 m from the pitch. The images were transferred to computer via USB and analysed in Windows Media Player (Microsoft Corporation, USA). All data were recorded in Microsoft Office Excel 2007 (Microsoft Corporation, USA) and subsequently exported to SPSS Statistics, version 22.0 (SPSS Inc., Chicago, USA). The MatLab software (R2014a, Mathworks Inc., USA) was used to process and analyse the data.

Data analysis

Position data – longitudinal (x-) and latitudinal (y-) coordinates – obtained through the GPS system were used to calculate the time–motion variables. Activity ranges selected were adapted from previous studies (Buchheit et al., 2010) as follows: (i) low-intensity running (LIR; running speed < 13.0 $km.h^{-1}$), (ii) high-intensity running (HIR; running speed from 13.1 to 16 $km.h^{-1}$), (iii) very high-intensity running (VHIR; running speed from 16.1 to 19 $km.h^{-1}$), (iv) sprinting (Sprinting; running speed > 19.1 $km.h^{-1}$). (v) total distance covered (TD). Very high-intensity activities (VHIA) were also calculated as VHIR plus Sprinting. The technical actions analysed were categorised into: (i) successful passing; (ii) unsuccessful passing; (iii) successful reception; (iv) unsuccessful reception; (v) dribble; (vi) shot framed; (vii) shot not framed; (viii) goal; (ix) interception. The level of inter-observer agreement to identify the technical actions was (Kappa = .84). Reliability was assessed by the authors coding three randomly selected matches and the data being compared to each other.

Statistical analysis

Results are expressed as means ± standard deviations. The normal distribution of the data was checked using the Shapiro–Wilks test. Dependent variables (i.e. running activities and technical actions) were analysed using a two-way analysis of variance (ANOVA) with repeated measures, where the pitch surface (AT, NT, and DF) and playing positions (CD, CF, CM, WM, and FB) were the Within-participant and between-participant factors, respectively. Mauchly´s test of sphericity was performed to verify any violations of sphericity that were corrected through the Greenhouse–Geisser adjustment (Bathke, Schabenberger, Tobias, & Madden, 2009). Effect sizes were reported as partial eta squared (η^2) obtained with the ANOVAs, following Cohen´s guidelines (Cohen, 1988): (i) $.01 \le \eta^2 < .06$ – small effect; (ii) $.06 \le \eta^2 < .14$ – moderate effect; and (iii) $\eta^2 \ge .14$ – large effect. The significant main effects of each factor were followed up with the *post hoc* Bonferroni corrected multiple comparisons test. All statistical analyses were carried out using SPSS Statistical Analysis Software (SPSS Inc., Chicago, USA) version 22.0 for windows.

Results

Player´s running activity

Surface-related running activity differences in performance were checked in TD, LIR and VHIR categories (Figure 1). It was verified that the TD covered by the players on artificial turf was significantly higher than on natural turf (e.g. η^2 = .09, p = .007). Also, there was a trend to the players to cover a greater distance in LIR and VHIR categories on the artificial turf compared to natural turf (e.g. η^2 = .062 and η^2 = .05 for LIR and VHIR, respectively, and all $p \le .05$). These differences were associated with small (≤ .06) and moderated effect sizes ($.06 \le \eta^2 < .14$).

The running activity differences across playing positions are presented in Table 1. There was a significant difference in HIR, TD ($p < .05$) and LIR categories

(p < .001) between playing positions on the three pitch surfaces. Central midfielders presented the greatest TD which was associated with the highest LIR values compared with other playing positions (p < .05). Conversely, central defenders covered the lowest TD (p < .05) while fullbacks showed the lowest LIR values (p < .05). Central defenders also showed lowest HIR values than other playing positions while central midfielders presented the highest values (p < .05). These differences were most evident on the dirt field.

Player´s technical performance

Surface-related technical actions differences in performance were checked in successful passing, unsuccessful passing and interceptions (Figure 2). There was a trend for a greatest successful passing on artificial turf than dirt field (e.g. η^2 = .052, p = .051). Conversely, the unsuccessful passing was greatest on dirt field than artificial and natural turf (e.g. η^2 = .155, p < .001). Finally, the interceptions were greatest on dirt field than natural turf (e.g. η^2 = .1087, p < .001). Dirt field was associated with large effect size ($\eta^2 \geq .14$) in unsuccessful passing. Player´s positions-related technical actions differences are presented in Table 2. There was a significant difference in successful passing, unsuccessful passing, dribble, shot framed and interceptions on the three surfaces (p < .05). Central midfielders presented the greatest

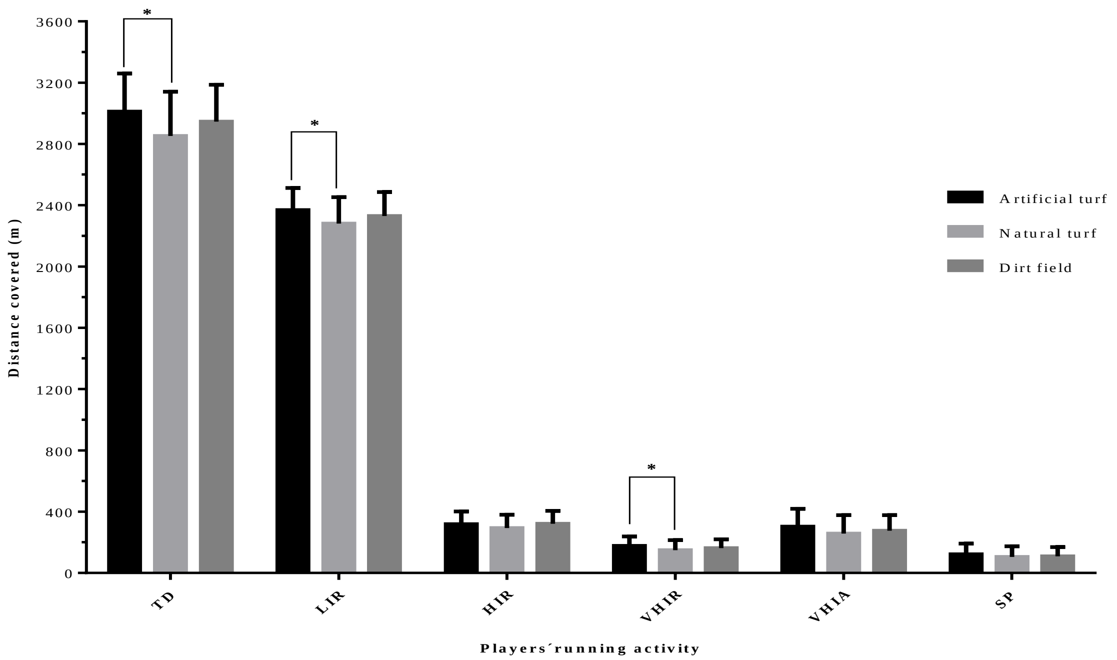

Figure 1. Players´ running activity on each pitch surface condition (mean±SD).
Note: Running activity categories: total distance covered (TD), low-intensity running (LIR; running speed < 13.0 km.h^{-1}), high-intensity running (HIR; running speed from 13.1 to 16 km.h^{-1}), very high-intensity running (VHIR; running speed from 16.1 to 19 km.h^{-1}) and sprinting (SP; running speed > 19.1 km.h^{-1}). Very high-intensity activities (VHIA) = VHIR + SP. Significant differences between conditions: ($p < .05$)*. Pitch surfaces: AT=Artificial turf; NT=Natural turf; DF=Dirt field.

successful passing than other positions, especially on dirt field ($p < .05$). On the other hand, centre forwards showed the greatest unsuccessful passing, which was associated with the highest unsuccessful reception. However, the main differences between playing positions were observed in dribble and interceptions ($p < .05$). Wide midfielders presented the greatest dribble number while central defenders showed the lowest number. Similarly, central defenders showed the greatest interceptions number whereas centre forwards presented the lowest number, independently of the pitch surface used ($p < .05$). Finally, it was clear that central midfielders and centre forwards presented the highest shot framed values while fullbacks showed the lowest values ($p < .05$). The differences were most evident on artificial turf and dirt field.

Discussion

The aim of this study was to investigate the effect of pitch surface on running activity and technical actions performed during soccer matches. The major findings were that the players’ running activity was significant different between artificial and natural turf, particularly in TD, LIR and VHIR categories, respectively. These findings are in contrast with (Andersson et al., 2008) who didn´t observe differences between artificial turf and natural turf on TD and LIR activities of adult professional players. The participants´ characteristics (adult professional players as opposed to non-elite young´s in the current study) as well as study design

Table 1. Running activity according to playing positions on each pitch surface (mean ±SD)

Running activity	Pitch Surfaces	All players (*n*=60)	Central defenders (CD) (*n*=12)	Centre forwards (CF) (*n*=6)	Central midfielders (CM) (*n*=18)	Wide midfielders (WM) (*n*=12)	Fullbacks (FB) (*n*=12)	*p*	Post hoc (Bonferroni)
HIR (running speed from 13.1 to 16 km.h^{-1})	**AT**	323.39±94.66	258.45±81.32	319.36±87.26	372.83±110.69	329.87±56.06	309.69±83.96	p=.022	CD<CM$^{(*)}$
	NT	302.10±97.82	240.63±59.76	274.33±82.71	362.23±101.04	289.37±90.15	300.01±100.51	p = .011	CD<CM$^{(*)}$
	DF	328.03±102.75	233.93±42.65	293.24±73.54	367.89±110.12	362.18±95.06	348.05±100.74	p = .002	CD<CM$^{(*)}$; CD<WM$^{(*)}$; CD<FB$^{(*)}$
LIR (running speed < 13.0 km.h^{-1})	**AT**	2384.34±205.91	2330.10±133.81	2429.70±130.37	2582.59±189.28	2277.73±161.70	2225.12±107.48	p < .001	CD<CM$^{(*)}$; CM>WM$^{(**)}$; CM>FB$^{(**)}$
	NT	2308.80±211.31	2251.73±119.34	2203.83±195.36	2493.41±210.57	2218.95±177.65	2231.27±164.70	p < .001	CD<CM$^{(*)}$; CF<CM$^{(*)}$; CM>WM$^{(*)}$; CM>FB$^{(*)}$
	DF	2365.88±224.58	2269.03±79.89	2234.93±205.56	2599.86±206.23	2316.61±188.58	2226.53±103.19	p < .001	CM>CD$^{(**)}$; CM>CF$^{(**)}$; CM>WM$^{(**)}$; CM>FB$^{(**)}$
SP (running speed > 19.1 km.h^{-1})	**AT**	116.80±78.44	85.62±52.42	138.70±43.69	86.50±67.63	163.29±98.45	136.49±83.57	p = .033	
	NT	82.49±119.60	26.97±124.16	61.71±179.58	47.70±113.01	81.40±167.24	73.82±175.15	p = .200	
	DF	85.22±121.10	49.18±98.85	95.63±169.85	49.71±108.23	84.54±184.04	64.64±181.01	p = .061	
TD	**AT**	3021.39±301.97	2834.96±201.40	3134.88±202.83	3229.24±304.23	2996.68±243.28	2864.02±290.29	p = .001	CD<CM$^{(*)}$; CM>FB$^{(*)}$
	NT	2885.89±320.69	2715.23±241.75	2779.02±323.10	3115.04±312.75	2804.21±304.37	2847.92±262.92	p = .004	CD<CM$^{(*)}$
	DF	2985.35±300.27	2718.86±132.87	2843.20±321.28	3234.08±253.71	3022.91±263.23	2912.26±230.03	p < .001	CD<CM$^{(**)}$; CD<WM$^{(*)}$; CM>CF$^{(*)}$; CM>FB$^{(*)}$
VHIA (calculated as VHIR plus Sprinting)	**AT**	290.54±129.55	229.92±71.27	363.16±107.46	243.09±112.06	366.62±135.19	309.93±157.22	p = .018	
	NT	253.18±124.39	207.85±115.29	276.42±90.68	231.48±119.12	279.29±111.93	293.35±160.32	p = .397	
	DF	270.16±119.71	200.44±39.55	302.11±65.30	247.01±117.30	318.68±128.20	310.09±156.90	p = .070	
VHIR (running speed from 16.1 to 19 km.h^{-1})	**AT**	170.49±66.70	138.89±37.21	219.17±70.59	155.60±62.88	199.79±49.49	170.79±89.30	p = .052	
	NT	149.37±68.65	128.31±46.33	152.24±43.92	150.45±75.01	150.56±64.83	166.22±92.50	p = .772	
	DF	162.67±63.47	121.31±29.79	164.96±46.26	165.66±68.08	178.65±61.37	182.41±78.92	p = .129	

Note: Running activity categories: total distance covered (TD), low-intensity running (LIR; running speed < 13.0 km.h^{-1}), high-intensity running (HIR; running speed from 13.1 to 16 km.h^{-1}), very high-intensity running (VHIR; running speed from 16.1 to 19 km.h^{-1}) and sprinting (SP; running speed > 19.1 km.h^{-1}). Very high-intensity activities (VHIA) = VHIR + SP. Significant differences between conditions: (p < .05)*; and (p < .001)**. Playing positions categories: CD=Central defenders; CF=Centre forwards; CM=Central midfielders; WM=Wide midfielders; FB=Fullbacks. Pitch surfaces: AT=Artificial turf; NT=Natural turf; DF=Dirt field.

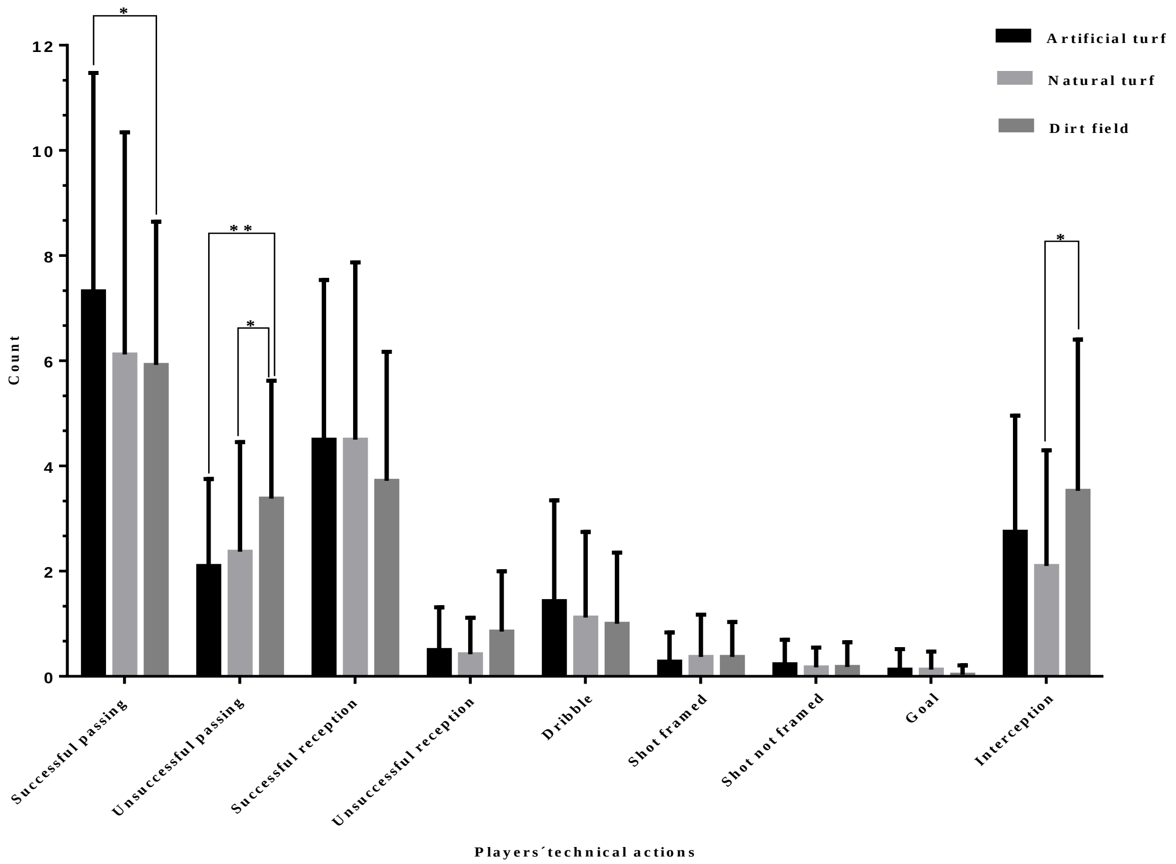

Figure 2. Players´ technical actions on each pitch surface condition (mean±SD).
Note: Significant differences between conditions: (p < .05)* and (p < .001)**. Pitch surfaces: AT=Artificial turf; NT=Natural turf; DF=Dirt field.

(games were played on a second-generation artificial turf and third generation artificial turf as opposed to natural turf, artificial turf, and dirt field in the current study) might explain the observed differences. Furthermore, it was found that soccer matches performed on natural turf showed lowest values in all categories while artificial turf presented highest values in all categories, except in HIR. The greater TD covered on artificial turf was associated with the greater amount of VHIA performed, particularly in the SP and VHIR categories. While we are not aware of any comparable data in the literature, this relationship is in line with the study by (Mohr et al., 2003) which assessed physical fitness, match performance and development of fatigue on professional top-class soccer players during competitive matches. Moreover, it can be hypothesised that the natural turf can increase the fatigue, constraining, therefore, the player´s running activity in the VHIA, SP and TD categories. Such hypothesis may result from the player´s inadaptability to natural turf, probably more physically demanding, impairing, in this way, their movements on the pitch. Also, may be possible that natural turf can express a reduced pace of the matches, induced by the efforts that the player develops to adapt and overcome the game constraints, reducing the amount of high-intensity running they perform (Bradley et al., 2009). A future study would be useful to investigate whether the running activity it is affected by surface-related fatigue.

Our results confirmed that regardless of the pitch surface used, the lowest distance covered by U14 non-elite players during 11-a-side soccer matches was undertaken at sprinting activity (running speed above 19.1 $km.h^{-1}$), which is in accordance with the previous studies performed with young elite players, adult non-elite players, and adult professional players (Bradley et al., 2010; Buchheit et al., 2010; Rebelo et al., 2014). However, if we consider the specificity of each surface, our data showed that the mean distance covered by the U14 nonelite soccer players in sprinting activity during actual matches was 3.9% on artificial turf and 2.8% on artificial turf and dirt field. Since we are not aware of any study that has compared the running activity of young players on the three pitch surfaces manipulated in our study, it can be supposed that the players tend to have a greater ability to perform high-intensity activities repeatedly (e.g. sprinting activity) on artificial turf than on natural turf and dirt field. The natural turf and dirt field surface characteristics may require additional muscle and metabolic capacity of the players to perform high-intensity activities repeatedly, such as sprint. In this perspective, it seems relevant that the coaches adapt the players-specific training regimes to the characteristics of the pitch surface, which can be a key factor to the development of players´ performance. Further investigations are however required to assess the potential advantages of each surface in the increase muscle and metabolic capacity of the players.

Table 2. Technical actions according to playing positions on each pitch surface (mean±SD).

Technical actions	Pitch Surface	All players (n=60)	Central defenders (CD) (n=12)	Centre forwards (CF) (n=6)	Central midfielders (CM) (n=18)	Wide midfielders (WM) (n=12)	Fullbacks (FB) (n=12)	p	Post hoc (Bonferroni)
Successful passing	AT	7.32±4.15	8.83±5.37	5.67±2.16	9.39±3.81	4.42±2.36	6.42±3.53	p = .006	CM>WM$^{(*)}$
	NT	6.12±4.22	7.56±5.71	5.67±3.08	8.00±4.36	3.83±2.66	4.58±2.61	p = .041	
	DF	5.92±2.73	5.17±2.59	4.00±1.79	7.94±2.51	4.83±1.99	5.67±2.71	p = .002	CD<CM$^{(*)}$; CF<CM$^{(*)}$; CM>WM$^{(*)}$
Unsuccessful passing	AT	2.10±1.65	2.08±1.24	1.17±1.33	2.89±1.46	1.17±1.03	2.33±2.35	p = .033	CM>WM$^{(*)}$
	NT	2.37±2.08	3.42±2.71	0.50±0.84	2.78±2.02	1.67±1.30	2.33±1.92	p = .035	CD>CF$^{(*)}$
	DF	3.38±2.24	4.33±2.81	3.33±1.51	3.00±1.91	2.75±2.05	3.67±2.54	p = .439	
Successful reception	AT	4.50±3.04	4.50±4.03	3.50±1.52	5.17±3.31	4.58±2.54	3.92±2.68	p = .754	
	NT	4.50±3.37	5.22±4.94	4.00±3.16	5.42±3.67	4.17±1.70	3.08±2.02	p = .405	
	DF	3.72±2.45	2.67±1.56	3.83±1.47	4.58±2.53	4.17±3.53	3.17±1.95	p = .299	
Unsuccessful reception	AT	0.50±0.81	0.33±0.89	1.17±1.17	0.39±0.50	0.83±1.03	0.17±0.39	p = .057	
	NT	0.42±0.70	0.50±0.80	1.17±1.17	0.33±0.49	0.25±0.62	0.25±0.45	p = .061	
	DF	0.85±1.15	0.25±0.62	1.17±2.04	0.94±1.06	1.50±1.31	0.50±0.52	p = .059	
Dribble	AT	1.43±1.92	0.08±0.29	0.50±0.55	2.17±2.18	3.00±2.17	0.58±0.79	p < .001	CD<CM$^{(*)}$; CD<WM$^{(**)}$; CF<WM$^{(*)}$; WM>FB$^{(*)}$
	NT	1.12±1.63	0.33±0.49	0.50±0.84	1.17±1.47	2.67±2.43	0.58±0.79	p = .002	CD<WM$^{(*)}$; CF<WM$^{(*)}$; WM>FB$^{(*)}$
	DF	1.00±1.35	0.25±0.62	1.00±1.11	1.06±0.99	2.17±2.08	0.50±0.80	p = .004	CD<WM$^{(*)}$; WM>FB$^{(*)}$
Shot framed	AT	0.28±0.56	0.00±0.00	0.50±0.55	0.61±0.70	0.25±0.62	0.00±0.00	p = .006	CD<CM$^{(*)}$; CM>FB$^{(*)}$
	NT	0.37±0.80	0.00±0.00	0.33±0.52	0.78±1.22	0.50±0.67	0.00±0.00	p = .033	
	DF	0.37±0.66	0.25±0.45	1.17±1.17	0.61±0.70	0.00±0.00	0.08±0.29	p = .001	CD<CF$^{(*)}$; CF>WM$^{(*)}$; CF>FB$^{(*)}$
Shot not framed	AT	0.23±0.47	0.08±0.29	0.33±0.52	0.50±0.62	0.08±0.29	0.08±0.29	p = .035	
	NT	0.17±0.38	0.00±0.00	0.17±0.41	0.33±0.49	0.17±0.39	0.08±0.29	p = .163	
	DF	0.18±0.47	0.25±0.45	0.33±0.82	0.28±0.58	0.08±0.29	0.00±0.00	p = .421	
Goal	AT	0.13±0.39	0.00±0.00	0.33±0.52	0.28±0.58	0.08±0.29	0.00±0.00	p = .128	
	NT	0.13±0.34	0.00±0.00	0.17±0.41	0.22±0.43	0.25±0.45	0.00±0.00	p = .177	
	DF	0.03±0.18	0.00±0.00	0.17±0.41	0.06±0.24	0.00±0.00	0.00±0.00	p = .320	
Interception	AT	2.75±2.21	4.58±2.61	0.33±0.52	3.08±1.94	1.25±0.97	3.11±1.68	p < .001	CD>CF$^{(**)}$; CD>WM$^{(**)}$; CF<CM$^{(*)}$; CF<FB$^{(*)}$
	NT	2.10±2.20	3.67±1.78	0.50±0.55	1.61±1.88	1.17±0.94	3.00±3.16	p = .004	CD>CF$^{(*)}$; CD>WM$^{(*)}$
	DF	3.53±2.87	6.25±3.31	0.67±0.82	3.44±2.38	1.58±1.17	4.33±2.35	p < .001	CD>CF$^{(**)}$; CD>CM$^{(*)}$; CD>WM$^{(**)}$; CF<FB$^{(*)}$

Note: Significant differences between conditions: ($p < .05$)*; and ($p < .001$)**. Playing positions categories: CD=Central defenders; CF=Centre forwards; CM=Central midfielders; WM=Wide midfielders; FB=Fullback. Pitch surfaces: AT=Artificial turf; NT=Natural turf; DF=Dirt field.

Irrespective of pitch surface, no differences between elite and non-elite U14 soccer players on TD, HIR, and VHIR activity were found. As observed in elite players (Goto et al., 2015) we also found that the average distance covered by non-elite U14 players was similar to elite players (i.e. ~ 2900 m per 30 min of 11-a-side game), of which 11% were covered by high-intensity running (speed from 13.1 to 16 km.h^{-1}), and

5.5% was covered by very high-intensity running (speed from 16.1 to 19 km.h^{-1}), respectively. These data suggest that the physical demands of U14 non-elite players can be like elite players if they are exposed to the same training conditions. However, caution is necessary when interpreting the results once that in the study of (Goto et al., 2015), the soccer match duration was 40 min × 2 and was performed on flat grass pitch, whereas in our study, the match duration was 30 min and was performed in natural turf, artificial turf and dirt field. Further studies are required to investigate the effects of the same constraints on elite and non-elite players to clarify these observations. At the same time, 3% of the activity was covered in sprinting (running speed > 19.1 km.h^{-1}), revealing that in the global picture the amount of sprinting activity performed by adult elite players is ~150% more than U14 non-elite players (Bradley et al., 2010). The mentioned differences can be explained by the effect of several factors, such as the age, height and/or body mass, hours of training accumulated, training conditions, anaerobic power, agility and aerobic endurance (Rebelo et al., 2013).

Since running activity was analysed on artificial turf, natural turf and dirt field during 11-a-side matches, direct comparisons with data from the literature are not possible. However, the present results extend the previous findings on positional differences of adult professional soccer players physical activities (Dellal, Moalla, Chamari, & Wong, 2010) as well as on the physical demands of adult professional soccer players during various 4-min small-sided games (SSGs) in comparison to 11-a-side matches (Dellal et al., 2012). For instance, between the playing positions of U14 non-elite players (Table 1), match analyses have demonstrated that running activity are position dependent, as verified with U13 to U18 elite players and adult professional players (Buchheit et al., 2010; Mohr et al., 2003). Whichever the pitch surface used, our results show that the central midfielders covered the highest TD, HIR and LIR while central defenders and fullbacks showed the lowest values, which contradicts the study conducted by (Dellal et al., 2010), whose results indicated that the centre forwards showed the lowest values. Probably, these differences were due to the characteristics of the analysed players, since in the mentioned study were analysed adult professional players, which have greater physical capacity than young players. Our findings suggest that central defenders are the least active players during soccer match, which can result from the central defender´s requirements, with offensive–defensive actions that may induce a smaller amount of forward, backward and sideways movement.

Additionally, the greater amount of TD, HIR and LIR covered by the central midfielders is probably related to their need to control the pitch´s centre by effective inter-player spacing (Gonçalves et al., 2014). According the mentioned authors, the central midfielders are the “core” of the pitch and probably a key determinant of the matches. This may place additional requirements on central midfielders, especially in relation to offensive–defensive actions that may necessitate a greater amount of forward, backward and sideways movements.

While speculative, it can be hypothesised that the player position may constrain a player´s actual running activity, with central defenders, due to their actions (with defensive prevalence) more tactically demanding and therefore tending to be more restricted in using their full physical capacities than other playing positions. Such trends have also been observed in a previous study conducted by (Buchheit et al., 2010) with U13–U18 elite soccer players. Additional analysis, using a more detailed physical analysis in combination with individual´s work-rate profiles, may support these ideas in future research.

Since it is well established that technical performance can change as a result of gradual changes in the player´s action ability or changes in playing conditions (Fajen, Riley, & Turvey, 2009) we expected differences on the player´s technical actions among pitch surfaces as well as between playing positions. Our findings showed that the successful passing was highest on artificial turf than natural turf and dirt field, which is in accordance with previous studies (Andersson et al., 2008; FIFA, 2007) performed with adult professional players. On the other hand, the unsuccessful passing was higher on dirt field compared to artificial turf and natural turf. Thus, it can be hypothesised that the artificial turf can provide a more effective interaction surface–ball and surface–player, which reflects the player´s ability to control the ball and, accordingly, can increase of the accuracy pass (Andersson et al., 2008; Burillo, Gallardo, Felipe, & Gallardo, 2014). Moreover, the surface´s stability can also restrict the ability and physical availability that players can offer and, in this way, change the profile of the game (Schlegel, 2009). Consequently, it is important that the players establish a good adaptation to the pitch surface, specifically if the technical development it is the main priority (Jones & Drust, 2007).

Our study also confirms that the amount of interceptions was highest on dirt field than on others surfaces, particularly comparing to natural turf. Despite the results don´t suggest significant differences, a consistently lower number of successful receptions, dribbles and goals were, however, recorded on dirt field. Accordingly, while we are not aware of any comparable data in the literature, this finding suggests that the dirt field does not promotes a skilful technical performance during soccer match, which may be a result of the instability caused by the respective surface (Praça et al., 2015). The game profile expressed on dirt field may be another possible explanation for the results found, suggesting that other factors can interfere with the player´s capacity to use the technical skills in the match context with maximum accuracy. As suggested by Praça et al. (2015) a proficient technical performance requires stable and flexible structures that are able to elicit similar responses in similar contexts. In this perspective, it may be suggested that the dirt field induces a less-structured game profile from the technical and tactical point of view, which can result from the greater difficulty that players feel to control the ball on this surface, making it complex to perform a game profile with more ball possession.

The knowledge on technical requirements between playing positions may provide to the coaches relevant insights that can be used on game concept designed for their team with a precise definition of the offensive and defensive phases that each game requires (Dellal et al., 2012). Our results showed that the player´s technical actions are position dependent (Table 2), as verified with adult professional players (Liu et al., 2016). The central midfielders showed the highest amount of successful passing and successful reception, regardless the pitch surface used. Moreover, they also expressed a greater amount of shot framed, particularly on artificial turf and natural turf. These results it seems to be indicative of the influence that central midfielders have in the team´s actions, participating actively at the offensive and defensive process with proper ball controls and passes, such as showed in previous research performed with adult professional soccer players (Dellal et al., 2012; Gonçalves et al., 2014; Liu et al., 2016). On the other hand, the central defenders showed greater amount of unsuccessful passing, mainly on natural turf and dirt field. Such trend has also been observed by Dellal et al. (2012), which suggests that central defenders are the players with weakest technical abilities. From our point of view, the coaches should be concerned in improving the technical abilities of the central defenders because in recent years the central defender´s offensive contribution involvement causes them to actively participate in the execution of their team´s game concept providing additional pass options when the team is in possession of the ball (Liu et al., 2016). In relation to the reflected dribbles, the wide midfielders were the positional role with greater amount performed while the central defenders expressed the smallest amount, regardless of the pitch surface used, as observed in adult professional players by Dellal et al. (2010). These results could be explained by the fact that wide midfielders have to promote, regularly, duels with purpose to acquiring a favourable position to make a goal assist while the central defender usually opt to receive and pass the ball quickly, assuming, in this way, less risks (Dellal et al., 2010).

Finally, in the defensive actions, it was demonstrated that central defenders and fullbacks showed highest amount of interceptions whereas the centre forwards showed the lowest amount. These results assumed greater expression on dirt field, which can be explain by the greater amount of inaccurate pass observed on this surface. Moreover, as suggested by Dellal et al. (2010), the centre forwards are often playing with their backs to the goal, which implies that they receive the ball with a defender to marking them, making it easier for the defenders to intercept the ball when he is positioned to the front of the matches. Studies matching technical to tactical analyses during soccer matches should however be performed in the future to clarify these observations. This kind of information is vital to improve the knowledge of the matches, quality of training and intervention of the coach, improving, in this way, the performance of the players and team.

Conclusions

This study provides some evidence that the running activity and technical actions of young soccer players can be influenced by the type of the pitch surface used as well as the player´s tactical positions. Furthermore, the physical and technical constraints induced by each pitch surface also reflect differences in the game profile expressed by the teams. The natural turf seems to lead to a decrease of running activity whereas the artificial turf induces a highest running activity. In addition, the dirt field seems to lead to an increase of unsuccessful technical actions while the artificial turf induces the increase of successful actions, probably explained by the interaction surface–ball and surface–player as discussed. The time–motion and technical variables helped to explain the reflected trends and contributed to a better understanding of the physical and technical requirements imposed on players as a function of the pitch surface used and their tactical function. These insights can provide the opportunity to the coaches to maximise the efficiency of their training sessions, providing relevant implications for enhancing technical and physical behavioural of developing players. Future studies should be combined with analyses of the tactical performance, such as the organisation of the players in the offensive and defensive phases.

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Study III.

In press

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Effects of pitch surface on displacement of young players during match-play

Abstract

The aim of this study was to analyse the effect of different pitch surfaces (artificial turf, natural turf and dirt field) on positioning and displacement of young soccer players (age: 13.4 ± 0.5 yrs; body height: 161.82 ± 7.52 cm; body mass: 50.79 ± 7.22 kg and playing experience: 3.5 ± 1.4 yrs). Data were collected using GPS units which allowed to calculate spatial distribution variability, assessed by measuring entropy of individual distribution maps (ShannEn). Ellipsoidal areas (m^2) representing players´ displacement on the pitch, centred on the average players´ positional coordinates, were also calculated, with axes corresponding to the standard deviations of the displacement in the longitudinal and lateral directions. Analysis of variance (ANOVA) was used to evaluate differences between pitch surfaces and across players´ positions. There was significant effect in positioning ($\eta^2 = 0.146$; $p < 0.001$) and displacement ($\eta^2 = 0.063$; $p < 0.05$) by the players between pitch surfaces. A dirt field condition induced an increase in the players´ movement variability, while players´ displacement was more restricted when playing on artificial turf. Also, there were significant effects on positioning ($\eta^2 = 0.496$; $p < 0.001$) and displacement ($\eta^2 = 0.339$; $p < 0.001$) across players´ positions. Central midfielders presented the greatest movement variability and displacement while fullbacks showed the lowest variability. Subsequently, the results may contribute to implement strategies that optimise players´ performance in different surface conditions.

Keywords: movement variability; spatial distribution maps; performance analysis; entropy; tactical demands.

Introduction

Youth soccer matches are played on natural and artificial turf surfaces. However, in certain regions of Africa and southern Europe many soccer matches are still being played on a dirt field surface. Although we know this reality, there are still many uncertainties concerning the influence of each pitch surface on the tactical demands of young players in match-play.

Soccer players´ performance is influenced by tactical, technical, physical and psychological factors (Stølen et al., 2005). More specifically, Impellizzeri and Marcora (2009) suggested that the tactical factor is one of the most important in the analysis of soccer matches. However, since the nature of a soccer match is highly dynamic and complex, assessing players´ tactical performance can be a demanding task (Gréhaigne et al., 2011). Therefore, some researchers suggest that the analysis of variability of players´ motion can be seen as an interesting method to identify and classify their performance from a tactical viewpoint (Couceiro et al., 2014). To assess it, a new set of technologies, such as those based on video tracking and global positioning systems (GPS) have contributed to new insights into the analysis of soccer players´ performance either in training or during a game (Cummins et al., 2013). Portable GPS devices provide spatial-temporal data with the reasonable accuracy for tracking players trajectories on the pitch (Coutts and Duffield, 2010; Gray et al., 2010). Positional data are critical to better understand players physical, technical or tactical demands (Cummins et al., 2013; Stølen et al., 2005). Moreover, they also enable to analyse the interactions between player´s trajectories, contributing to understanding the intricate motion patterns of players, which are critical in the analysis of tactical performance (Silva et al., 2014a).

Previous studies have demonstrated that analysis of how the players manage the space (Bartlett et al., 2012), measuring the action zone variability, may be a viable method to assess the players tactical performance (Gréhaigne, 2011; Gréhaigne et al., 2001). For instance, Jones and Drust (2007) suggested that if players restricted their action zones to specific pitch zones, this could be interpreted as a more structured game, played according to the players´ positions and specific functions. Other studies have suggested that players´ spatial distribution variability on the pitch can be a relevant concept to quantify their individual movements from a tactical perspective

(Silva et al., 2014a; Silva et al., 2015). For instance, a study conducted by Silva et al. (2014a) concluded that national-level soccer players presented higher variability than regional-level players when playing small-sided games in smaller areas, which may indicate that players of different skills respond in a different manner to the same task constraints. According to the aforementioned authors, greater uncertainty in the players´ behavioural modes during small-sided games may be associated with more variable action zones. Thus, it seems relevant to measure the variability to capture and interpret the meaning of situations that occur during soccer matches.

Typical measures of variability from spatial-temporal data include the range, standard deviation or the coefficient of variation, along with central tendency measures (mean, median, and mode). These linear quantities are complemented with more sophisticated analysis, such as the one based on entropy values obtained from player´s spatial distribution maps (Couceiro et al., 2014; Silva et al., 2014a; Silva et al., 2015). The entropy, originally described by Shannon (1948), is a non-linear variable that can be used to express the uncertainty of locating the player in a specific region of the soccer pitch (Silva et al., 2014a). Normalized entropy ranges from 0 to 1, i.e., from highly predicted positions of the players on the pitch to highly variable or unpredicted positions (Silva et al., 2014a). Therefore, to the authors previously mentioned, entropy can be a valuable tool to quantify players´ performance from a tactical perspective.

Players´ relative positioning on the pitch, centred on their average positional coordinates, with axes corresponding to the displacement´s standard deviations in the longitudinal and lateral directions of the pitch, can also provide additional information on tactical behaviour (Silva et al., 2014b; Yue et al., 2008). In this context, a study by Silva et al. (2014b) analysed the distribution of players´ movement coordinates in the longitudinal and lateral pitch directions and confirmed that national-level soccer players displayed differentiated distributions in the longitudinal direction, while regional-level players tended to play on very similar longitudinal coordinates of the pitch, only varying their positioning along the lateral direction. In addition, Yue et al. (2008) concluded that forwards constituted the positional role with the largest range of movements compared with other positions, which means that they have to move in order to provide pass solutions to team mates as well as to escape from the opponent´s zone.

Few studies have examined the effect of the pitch surface on players´ demands during competitive soccer matches. To date, it has been demonstrated that a pitch surface neither influences tactical performance (Santos et al., 2013), nor the players´ movement patterns (Andersson et al., 2008). However, Folgado et al. (2007) showed that the number of successful passes was higher in the natural turf condition compared to the sand surface. In addition, Andersson et al. (2008) showed that ball possession and the number of passes increased 20% in the artificial turf condition compared to the natural turf.

Despite the importance of these studies, it has not yet been investigated whether the pitch surface influences the positioning and displacement of young soccer players. This information could provide coaches and sports managers with an opportunity to adapt and overcome the specific constraints of the pitch surfaces on the tactical profile of the players and respective teams. Moreover, it may maximize the effectiveness of training sessions and implement strategies that could improve players´ tactical performance during match-play.

The players and, ultimately the team, are expected to behave in a way that reflects the concept of game designed by coaches. However, the players´ intentional actions can be constrained by the effect of the surface where the soccer match is performed. In this context, it is relevant to analyse the player´s displacement to adapt and overcome possible constraints imposed by the surface. In this sense, this insight may provide additional information about the specific requirements of each surface and a prerequisite for coaches to improve tactical performance of players and teams, either in training or a game context. Therefore, this study aimed (1) to analyse the displacement variability patterns of players on artificial turf (AT), natural turf (NT) and a dirt field (DF) and; (2) to determine whether there were differences in the spatial distribution variability across players´ positions. It was hypothesized that the three pitch conditions would induce differences in positioning and displacement of the players.

Methods

Participants

Sixty-six male U-14 soccer players, organized into three teams of twenty-two participated in the study (age: 13.4 ± 0.5 years; body height: 161.82 ± 7.52 cm; body mass: 50.79 ± 7.22 kg). Players were selected according to the coach´s subjective appraisal of their ability. All players competed at a regional-level exhibiting match and training experience of 3.5 ± 1.4 years. The U-14 age-group was chosen because 40% of soccer matches were still played on a dirt field, at the regional championship U-14 (AF Porto, Portugal). The participants´ (teams and players) selection was conducted in accordance with the following criteria: 1) teams and players registered at the Porto Football Association championship; 2) teams and players from the same competitive level. All players and their tutors were informed about the research procedures, requirements, benefits and risks, and written informed consent was obtained from parents. The study protocol followed the guidelines stated in the Declaration of Helsinki and was approved by the local Ethics Committee.

Measures

The positional data were used to calculate: (1) players´ spatial distribution variability, assessed by measuring the entropy of individual spatial distribution maps (Shannon, 1948; Silva et al., 2015). These maps were obtained from discretization of the pitch into sectors of 1 m^2, allowing to calculate the amount of time spent in each sector, normalized to total match duration to produce spatial probability distributions. In this way, a normalized value of entropy, ranging from 0 to 1, was calculated to quantify the uncertainty of locating each player in a specific location of the pitch. A low entropy value (near zero) indicating a sharply peaked distribution, suggests the player´s position can be easily predicted. On the other hand, a high entropy value (near 1) corresponds to a uniform distribution and suggests the player exhibits high spatial distribution variability or that its position is highly variable and unpredictable (Silva et al., 2015). Taking into consideration the participant´s experience, the entropy was also related with team tactical performance. Thus, teams with players with high entropy values were interpreted as using a game style that promoted positional exchanges between players and more diversified tactical functions. On the other hand, teams with players with low entropy values were interpreted as using a game style based on more consistent displacement and more specific tactical functions; (2) the covered area by players in the pitch surface, assessed by measuring the area of ellipses representative of players´ pitch displacement, centred on the average positional coordinates of the players, with axes corresponding to the standard deviation of displacement in the longitudinal and lateral directions of the pitch (Zengyuan et al., 2008). Through elliptic forms we evaluated qualitatively the main directions of the players movements and their distribution and relative positioning on the pitch (Silva et al., 2014b). The ellipse areas were also calculated to provide quantitative information of the space predominantly used by each player during soccer matches.

Design and procedures

During three weeks, always on Sunday, a total of 9 soccer matches were performed and analysed, in the following condition: week (1) – 3 matches on artificial turf; week (2) – 3 matches on natural turf; week (3) – 3 matches on a dirt field. The teams and players who participated in the study were always the same and all soccer matches were played using 1-4-3-3 tactical structure, the most frequent in Portuguese youth teams (Rebelo et al., 2014). The players were classified according to their playing positional role: 1) central defenders (DC, n = 12); 2) centre forwards (CF, n = 6); 3) central midfielders (CM, n = 18); 4) wide midfielders (WM, n = 12); 5) fullbacks (FB, n = 12). The goalkeepers participated in the matches but were excluded from the analysis. The matches were played according to soccer rules, except match duration (30min, without breaks) and players´ substitution (not allowed). The pitch size was adjusted to standardize the measure for all conditions (length: 100 m, width: 64 m). Six extra soccer balls were always available near the goalposts and on the side of the pitch for prompt replacement when the ball left the playing area. All matches were proceeded by a planned, standardised warm up of 15 min comprising running activities, small-sided games and stretching. Following this period, the players simulated a match during two periods of 2 min, interspersed by 1 min of passive recovery. All games were played between 9 and 11 a.m., under similar climatic conditions.

Each player carried a global positioning tracking device (Qstarz, Model: BT-Q1000eX) that recorded his 2D positional coordinates at a sampling frequency rate of 10 Hz. The GPS device was placed on the upper back of the player (using an appropriate harness). The playing surfaces were calibrated with the coordinates of four GPS devices stationed in each corner for approximately 4 min. The absolute coordinates of each corner were calculated as the median of the recorded time series, providing robust measurements to typical fluctuations of the GPS signals. These absolute positions were also used to define the reference Cartesian coordinate systems for each pitch, with its origin placed at the pitch centre. GPS longitudinal and latitudinal (spherical) coordinates were converted into Euclidean (planar) coordinates with the Haversine formula (Sinnott, 1984). Fluctuations in players positions were reduced using a moving average filter with a time scale of 0.2s and data resampling was employed to synchronize the time series of all players within each soccer match (Silva et al., 2014a; Silva et al., 2015). All data were recorded in Microsoft Office Excel 2007 (Microsoft Corporation, USA) and subsequently exported to SPSS Statistics, version 22.0 (SPSS Inc., Chicago, USA). MatLab software (R2014a, Math works Inc., USA) was used to process and analyse the data.

Statistical analysis

Results are expressed as means ± standard deviations. A two-way analysis of variance (ANOVA) with repeated measures was employed to evaluate the differences in the described variables between each pitch surface. The Mauchly´s test of sphericity was performed on all data to verify any violations of sphericity that were corrected through the Greenhouse-Geisser adjustment (Bathke et al., 2009). Effect sizes were reported as partial eta squared (η^2) obtained with the ANOVAs, following Cohen´s guidelines (Cohen, 1988): (i) $0.01 \leq \eta^2 < 0.06$ – small effect; (ii) $0.06 \leq \eta^2 < 0.14$ – moderate effect; and (iii) $\eta^2 \geq 0.14$ – large effect. Post hoc analysis was performed using the Bonferroni adjustment. All statistical analyses were carried out using SPSS Statistical Analysis Software (SPSS Inc., Chicago, USA) version 22.0 for Windows.

Results

Spatial distribution

The entropy values were higher on the dirt field compared to the other pitch surfaces (Figure 1). ANOVAs yielded a main effect for pitch surfaces $F(2.110) = 9.417$; $p < 0.001$, $\eta^2 = 0.146$; $\pi = 0.977$. Post-hoc analysis revealed significant differences between a dirt field and artificial turf ($p = 0.019$) and natural turf ($p < 0.001$). Between the artificial turf and natural turf no significant differences were found ($p = 0.708$).

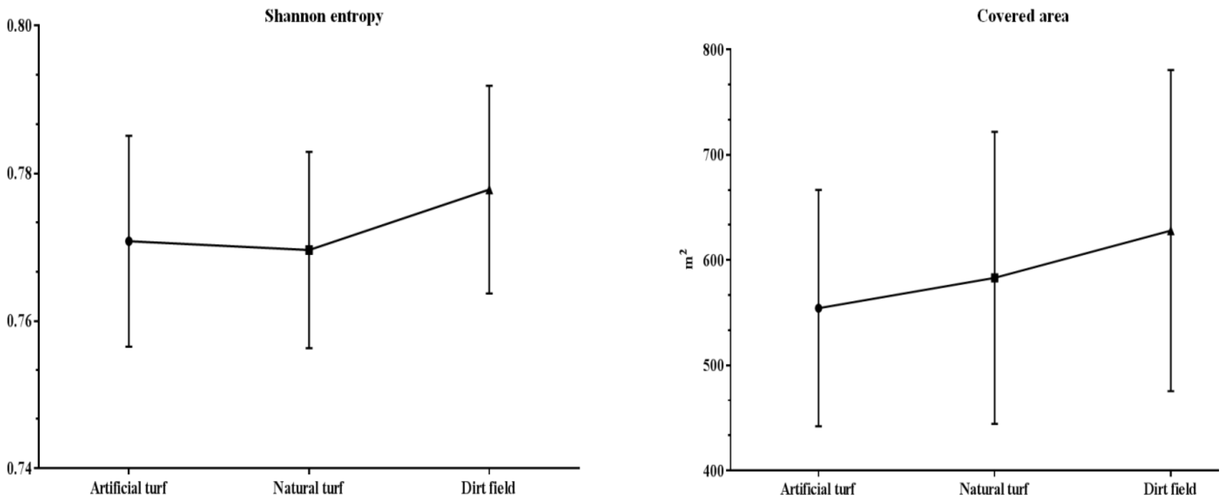

Figure 1. Mean values for Shannon entropy and covered area of players on each pitch surface. Error bars represent standard deviation.

Figure 2 presents an exemplar spatial distribution maps of players for each pitch surface, highlighting lower variability in spatial distribution for the natural turf surface than other surfaces.

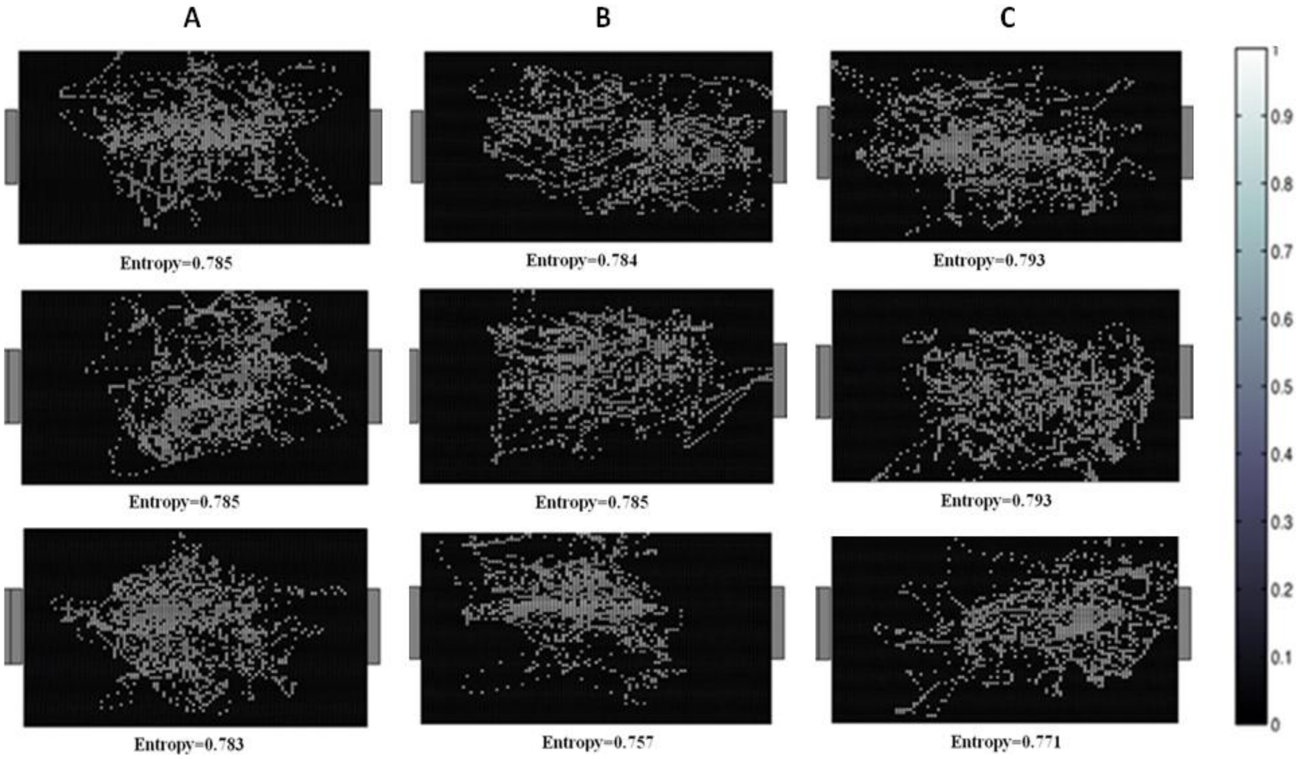

Figure 2. Spatial distribution maps of players to each pitch surface condition. A) artificial turf; B) natural turf; C) dirt field.
Note: The values of Shannon entropy presented represents the mean values of the players on each pitch surface and soccer match performed.

Relative positioning

Figure 3 illustrates the ellipses areas, centred on the average of the players´ positional coordinates, with semi-axes that correspond to the standard deviations of displacement in the longitudinal and lateral directions on each pitch surface. The ellipses areas of the artificial turf show less eccentricity and are more overlapping compared to other surfaces.

ANOVAs yielded a significant effect of the pitch surface on the mean area covered by the players $F(2.110) = 3.667$, $p < 0.05$, $\eta^2 = 0.063$; $\pi = 0.664$ (Figure 1). Post-hoc analysis showed significant differences between the dirt field and artificial turf ($p = 0.012$). However, no differences were found between natural turf and dirt field ($p = 0.582$) nor between natural turf and artificial turf ($p = 0.627$).

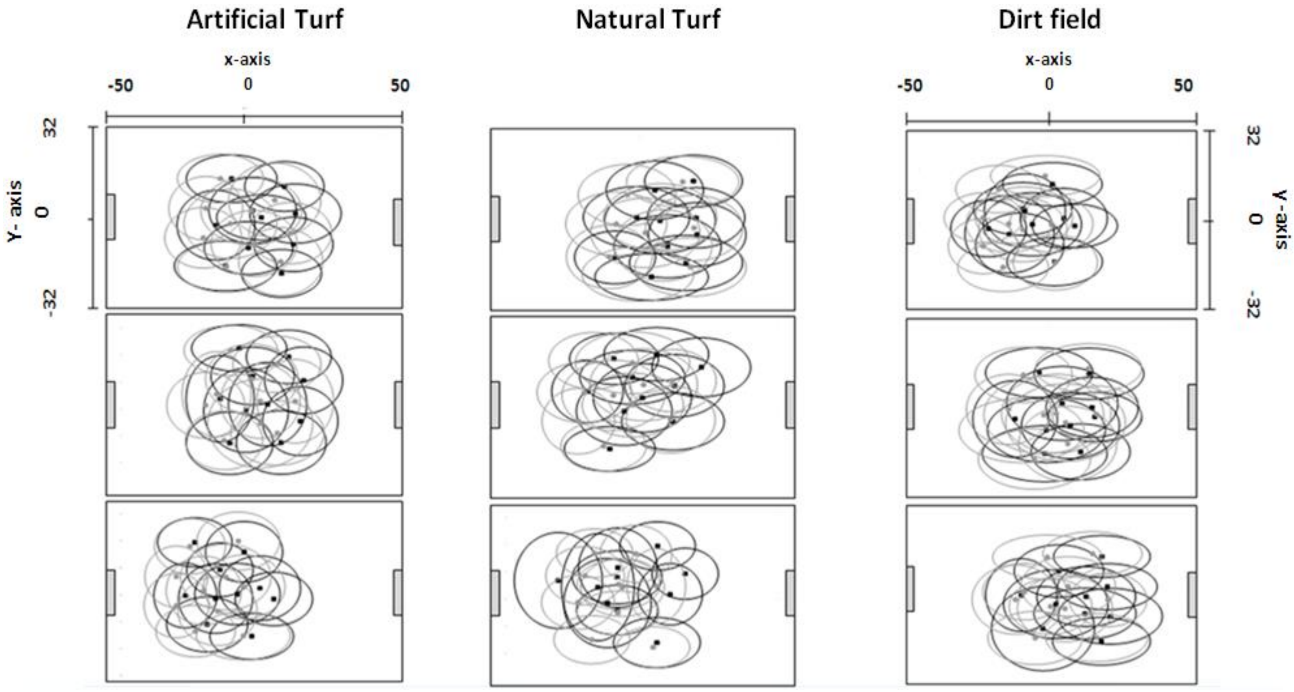

Figure 3. Players´elliptical areas on each surface. Black and grey ellipses depict the players´ major displacements of each team, respectively. Lateral (y-axis) and longitudinal (x-axis) depict pitch coordinates.

Spatial distribution and relative positioning across players´ positions

The differences on spatial distribution and mean area covered by the players across their positional role are presented in table 1. Significant differences in ShannEn values were observed across players´ positions in all pitch surface conditions $F(4.55) = 13.51$; $p < 0.001$, $\eta^2 = 0.496$; $\pi = 1.000$ (table 1). Specifically, central midfielders presented the greatest ShannEn values compared with other players´ positions, while fullbacks showed the lowest values ($p < 0.05$). The differences were most evident on the dirt field.

Table 1. Entropy values and mean area covered according to players' positions on each pitch surface (mean ±SD)

Variable	Pitch Surface	All players (*n*=60)	Central defender (CD) (*n*=12)	Centre forward (CF) (*n*=6)	Central midfielder (CM) (*n*=18)	Wide midfielder (WM) (*n*=12)	Fullback (FB) (*n*=12)	P	Post hoc (Bonferroni)
Shannon entropy	AT	0.771 ± 0.14	0.768 ± 0.08	0.779 ± 0.07	0.782 ± 0.01	0.764 ± 0.02	0.759 ± 0.011	*p*<0.01	CD<CM(*) CF>FB(*) CM>WM(*) CM>FB(**)
	NT	0.769 ± 0.01	0.767 ± 0.01	0.767 ± 0.01	0.781 ± 0.01	0.765 ± 0.01	0.762 ± 0.02	*p*<0.001	CD<CM(*) CM>WM(*) CM>FB(*)
	DF	0.778 ± 0.01	0.771 ± 0.01	0.774 ± 0.01	0.791 ± 0.01	0.776 ± 0.01	0.769 ± 0.02	*p*<0.001	CD<CM(**) CF<CM(*) CM>WM(*) CM>FB(**)
Covered area	AT	554.4 ± 112.3	522.1 ± 67.3	578.2 ± 87.9	626.6 ± 140.9	543.6 ± 92.5	477.2 ± 61.4	*p*=0.003	FB<CM(*)
	NT	583.2 ± 138.8	545.1 ± 107.9	583.5 ± 171.4	640.6 ± 138.7	598.1 ± 161.9	520.3 ± 104.1	*p*=0.157	
	DF	628.1 ± 152.6	554.7 ± 135.7	574.1 ± 92.3	731.2 ± 160.8	642.3 ± 156.9	549.8 ± 86.8	*p*=0.004	CM>CD(*) CM>FB(*)

Note: Significant difference across players' positions; (p≤0.05); and (p≤0.001)*. Pitch surface conditions. AT) artificial turf; NT) natural turf; DF) dirt field*

With regard to the mean area covered, significant differences were observed across players´ positions on artificial turf; $F(4.55) = 4.465$; $p = 0.003$ and dirt field

$F(4.55) = 4.425$; $p = 0.004$ respectively. No differences were found on natural turf (table 1). The central midfielders presented the greatest mean area covered while fullbacks covered the lowest ($p < 0.05$).

Discussion

The aim of this study was to analyse displacement and positioning of players during soccer matches performed on artificial turf, natural turf and a dirt field. For this purpose, variability of the respective spatial distribution was evaluated, and the mean area covered by each player was quantified.

Spatial distribution variability

The major findings were that the action zones of players were more restricted on artificial turf and natural turf than on a dirt field surface, which reveals more uncertainty in the behavioural modes of players on a dirt field. The results showed that players explored more variable areas of the pitch on the dirt field, which can be confirmed by the spatial distribution of players in different pitch conditions (Figure 2). This is probably due to increased irregularity that the dirt field usually presents, reflecting, therefore, more unstable behaviours. Thus, the players´ spatial distribution seems to provide relevant information about the tactical roles or style of play for each match-play condition, as observed by Silva et al. (2015).

The Shannon entropy values showed that players´ spatial distribution variability was significantly different in the three surfaces, especially between the dirt field and other surfaces. In general, during pitch surface manipulations, the higher spatial distribution variability was verified on the dirt field, which may result from greater flexibility of movement that players perform to adapt to the surface conditions and ball trajectories, probably more unpredictable on this surface. Thus, the greater variability observed on the dirt field expresses the continuous effort of the players to adapt to the characteristics of this surface, which seems to induce a greater number of unexpected events and specific restrictions in the game profile. This is non-systematic variability, which reflects unintentional movements or actions that probably were not previously defined. Such characteristics of movement or actions may constraint tactical behaviour of players and teams, contributing, for instance, to inducing undefined tactical functions to players as well as a more individualistic team game profile (Folgado et al., 2014). On the other hand, artificial turf and natural turf reflected less variability, characterized by being under control of players and expressing their intentional and systematic movements or actions. Accordingly, the game profile on these surfaces was more structured from the tactical point of view, where the players demonstrated a more balanced relationship between lateral and longitudinal movements (Silva et al., 2015). In this context, it can be hypothesised that the pitch surface characteristics affect players´ behaviour, constraining their variability of movements and actions. In addition, the nature and properties of the surface also seem to influence characteristics of the game (Andersson et al., 2008; Stiles et al., 2009), which was reflected in the trend to a direct and less structured game profile on the dirt field compared to artificial turf and natural turf.

Relative positioning

Considering to the mean area covered by players, our results indicate that the dirt field surface presented a larger mean area than other surfaces, especially in relation to artificial turf. While we are not aware of any comparable data in the literature, it can be hypothesized that the natural turf, but especially dirt field surface, induces an increase in the mean area covered by players. Probably, this trend may result from effects that these surfaces may induce on certain indicators, such as the velocity or trajectory of the ball as well as players´ running performance, impairing in this way players´ movement on the pitch.

Analyzing the ellipse shapes, it was found that artificial turf condition induced less eccentricity and was more overlapping compared to the natural turf and dirt field (Figure 3), which reflects a more balanced configuration of different sections of the pitch. This elliptical configuration suggests a greater coordination between players, reflecting a more structured and collective game profile (Bartlett et al., 2012). In this context, it seems that artificial turf promotes a tactically more balanced game, expressed in smaller eccentricity of the shapes configuration on this surface, which was revealed by longitudinal and lateral movements with a similar amplitude. This evidence was not that clear on other pitch surfaces, especially on the dirt field, where the longitudinal displacement of players in the pitch was more pronounced. Thus, it can be hypothesized that the dirt field surface induces a game profile dominated by long passes rather than a tactically elaborated game concept, where ball circulation predominates (Silva et al., 2014b; Stiles et al., 2009). This information could be valuable for coaches that intend to improve tactical performance of the players and respective teams.

Spatial distribution and covered area across players´ positions

Analysing the ellipse shapes, it was found that artificial turf condition induced less eccentricity and was more overlapping compared to the natural turf and dirt field (Figure 3), which reflects a more balanced configuration of different sections of the pitch. This elliptical configuration suggests a greater coordination between players, reflecting a more structured and collective game profile (Bartlett et al., 2012). In this context, it seems that artificial turf promotes a tactically more balanced game, expressed in smaller eccentricity of the shapes configuration on this surface, which was revealed by longitudinal and lateral movements with a similar amplitude. This evidence was not that clear on other pitch surfaces, especially on the dirt field, where the longitudinal displacement of players in the pitch was more pronounced. Thus, it can be hypothesised that the dirt field surface induces a game profile dominated by long passes rather than a tactically elaborated game concept, where ball circulation predominates (Silva et al., 2014b; Stiles et al., 2009). This information could be valuable for coaches that intend to improve tactical performance of the players and respective teams.

Conclusions

This study concludes that young soccer players perform more unstable and random movements in the dirt field, suggesting that this surface can be used by coaches as a useful tool for training players´ technical and tactical skills along their learning pathways. On the other hand, the artificial turf promotes a more structured style of play from a tactical viewpoint, demonstrating that it can be an excellent alternative to the natural turf to perform formal games, which can be used by national governing bodies to implement effective formal soccer activities in their youth development system (Ford et al., 2012). Our findings also showed that there were significant differences across the positional roles of players in the range of movement and displacement, suggesting that coaches should pay attention to the design of their training sessions and to constructing training units according to the requirements and adaptations of the respective positional role. Future studies could identify other specific conditions that may influence players´ tactical behaviours, such as the players level (elite and non-elite), different age-groups and different team formations (play systems), to provide deeper understanding of the players´ actions and tactical relations during games.

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CHAPTER V

Published

Study IV.

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Match-running performance of young soccer players in different game formats

Abstract

Present study aimed to analyse the effect of game format, age-group, and playing position on match-running performance variables of soccer players (age ranging from 6.94 ± 0.7 to 13.46 ± 0.5 yrs; height ranging from 125.36 ± 6.04 to 159.16 ± 7.78 cm; weight ranging from 27.16 ± 5.75 to 49.89 ± 8.89 kgf). Match-running variables were assessed using global positioning system technology. Results suggest that game formats that game formats, which include more players have a significant effect on match-running variables than those having fewer players ($p < 0.001$). Moreover, oldest age-groups covered significantly higher distances in all categories than younger groups, total distance (TD): $\eta^2 = 0.32$, $p < 0.001$; low intensity running (LIR): $\eta^2 = 0.09$, $p < 0.001$; high intensity running (HIR): $\eta^2 = 0.25$, $p < 0.001$; very high intensity running (VHIR): $\eta^2 = 0.34$, $p < 0.001$; very high intensity activity (VHIA): $\eta^2 = 0.42$, $p < 0.001$; and sprinting (SP): $\eta^2 = 0.41$, $p < 0.001$). Match-running variables also differ among playing positions. Defenders covered lowest TD and HIR in all age-groups; midfielders covered highest TD and LIR in all age-groups ($p < 0.001$); forwards covered highest VHIR, VHIA, and SP in U14 age-group. Defenders covered lowest TD, LIR, HIR, and VHIR; midfielders covered highest TD and HIR regardless game format ($p < 0.001$); forwards covered highest VHIR, VHIA, and SP in 11v11 format ($p < 0.001$). These findings can provide an opportunity for coaches to maximise the efficiency of their training sessions.

Keywords: Time-motion; GPS, performance analysis; physical demands; team sport

Introduction

Official soccer matches of youth leagues are being performed in different game formats according to the development stages of the players. Variables such as pitch size, number of players, and match duration are being adapted to the age of the players. The most used strategy is to increase progressively the number of players and the pitch size up to the 11v11 game format. For instance, from Under-8 (U8) up to Under-14 (U14) age-groups, the European countries are promoting official soccer matches with 5v5, 7v7, and 9v9 formats before 11v11 (Brito, Duarte, Diniz, Maia, & Garganta, 2017). However, still there are many uncertainties concerning the physical requirements of each game format (Stratton, Reilly, Williams, & Richardson, 2004) and the effects they have on young players either in training or competition (Castellano, Puente, Echeazarra, Usabiaga, & Casamichana, 2016). Therefore, the assessment of the match-running performance of youth players on different game formats can be relevant to develop and optimise preparation regimes to respond to the specific demands of each format, which may have practical implications on improving long-term interventions either in training or game conditions.

A new set of technologies, such as those based on video tracking and global positioning systems (GPS), has been contributing for new insights on the analysis of soccer players´ performance either in training or game (Carling, Bloomfield, Nelsen, & Reilly, 2008; Cummins, Orr, O'Connor, & West, 2013; Gabbett &Mulvey, 2008). Portable GPS devices provide time-motion data with reasonable accuracy, enabling the analysis of parameters such as distance, speed, and acceleration (Gabbett & Mulvey, 2008; Gaudino, Alberti, & Iaia, 2014). These quantities will contribute to identify players´ physical demands during training or game sessions (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010). Moreover, the possibility of gathering time-motion data, using relatively high acquisition frequencies (e.g. 10 Hz), also contributes to calculate and analyse the profiles of speed and acceleration of the players, which is relevant to characterise the players´ movement, load, and injury risk (Casamichana, Castellano, Calleja-Gonzalez, San Román, & Castagna, 2013; Varley & Aughey, 2013). Match-running performance data are typically related with speed profiles, which range from quiet or walking speeds to sprint (Dellal et al., 2012; Goto, Morris, & Nevill, 2015a).

Most of the research conducted in this area has been made in elite context (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Bradley et al., 2009) reflecting a shortage of studies with non-elite young players (Buchheit et al., 2010; Castagna, D'Ottavio, & Abt, 2003; Goto et al., 2015a; Rebelo, Brito, Seabra, Oliveira, & Krustrup, 2014). Thus, information regarding the match-running performance of non-elite young players would allow the technical staff to better understand players´ performance and improve the quality of technical staff interventions either in the preparation of training sessions or competitions. In fact, there is emerging evidence suggesting that the competitive level, age-group, and playing positions may affect soccer players´ running activity (Buchheit et al., 2010; Harley et al., 2010; Waldron &Murphy, 2013). For instance, a study conducted by (Goto, Morris, & Nevill, 2015b) demonstrated that total match running distance increases around 33% with age, from ~5800 m for the U11 to ~7700 m for the U15. Speed also increased (~18%) from ~5.7 km.h^{-1} (U11) to ~6.7 km.h^{-1} (U15). Concerning match running profiles, Rebelo et al. (2014) demonstrated that U17 non-elite soccer players covered a mean distance during 11v11 soccer match of ~6000 m, with an average speed of 4.8 ± 0.4 kmh^{-1} (ranging from 3.8 km.h^{-1} to 5.0 km.h^{-1}) and 12% on high-intensity activities (HIAs) (757 m). On the other hand, a study performed in professional context suggested that players were able to cover a distance of ~11,000 m during a 11v11 soccer match, of which 25% was in high-intensity running (HIR), 9% very high-intensity running (VHIR) and the vast majority at low intensity (Bradley et al., 2010). Regarding playing positions, previous studies performed with young players (13 to 18 years old) and adults/seniors (>18) demonstrated that the central defenders seem to cover fewer distances than all other positions; the central midfielders, fullbacks, and central defenders covered a lowest distance on HIR; and the wide midfielders and forwards covered a greater distance on VHIR activity (Bradley et al., 2010; Buchheit et al., 2010). Moreover, it is assumed that game format can also influence the players´ physical demands, reflecting differences related with the game format on match-running performance of the players during soccer matches. However, most of the previous research has been conducted in small-sided-games (SSGs) context (Brandes, Heitmann, & Müller, 2012; Castellano, Casamichana, & Dellal, 2013; Dellal et al., 2012; Hill-Haas, Dawson, Coutts, & Rowsell, 2009; Köklü, Ersöz, Alemdaroğlu, Aşç, & Ozkan, 2012). Consequently, there is little scientific evidence relating how different game formats used in competition context affect the performance of young players along their developmental process (Capranica, Tessitore, Guidetti, & Figura, 2001).

A previous study analysed the physical demands of U13 and U16 elite players in soccer matches performed in 7v7 game format, suggesting that there were no differences on mean distance covered between U13 (5228m) and U16 (5392m) (Barbero-Álvarez, Barbero-Álvarez, Granda, & Gómez, 2009). Another study conducted by (Randers, Andersen, Rasmussen, Larsen, & Krustrup, 2014) also evaluated the activity profile of non-elite and elite young players (U10 and U13) in two game formats (i.e. the U10 in 5v5 and 8v8 game formats whereas the U13 in 8v8 and 11v11 formats). The main findings suggested that the U10 covered lower distance at HIR in 5v5 game format than 8v8; the U13 covered lower total distance in the 8v8 game format (1821 m) than 11v11 (2038 m); and U13 elite players covered a significantly greater total distance (2088 m) than recreational players (1764 m). In its turn, Castellano, Puente, Echeazarra, and Casamichana (2015) investigated the influence of the number of players and relative pitch area per player on physical demands of U13 elite players during different game formats (i.e. 7v7, 9v9, and 11v11) and concluded that the higher demands on players activity were more related with the increase of the relative pitch area per player than the decrease on the number of players per team.

Despite the previously mentioned studies, to our knowledge, no study has yet examined the match-running performance profiles of young non-elite soccer players according to the most used game formats along their development stages (i.e. 5v5, 7v7, 9v9, and 11v11) for a wide range of combined age-groups (i.e. from 8 to 14 years old). Quantifying individualised speed thresholds for assessing running performance upon different official game formats may provide some evidence how to shape the game format to the characteristics of players. Therefore, the purpose of this study is: (1) to examine the match-running performance of young soccer players associated with four game formats (5 vs. 5, 7 vs. 7, 9 vs. 9, and 11 vs. 11) when the relative space per player was kept constant; (2) to assess the match-running performance of young soccer players in the U8 to U14 age-groups; (3) to determine whether there are differences on match-running performance between playing positions. It was hypothesised that: (1) the game formats with more players have a significantly greater effect on match-running performance than the game formats with less players; (2) the oldest age-groups cover a significantly highest distance in each match-running category than youngest groups; and (3) the match-running performance features differ among playing positions due to the specific roles that each player performs during the match.

Methods

Participants

One hundred and ninety-seven non-elite young soccer players belonging to four different age-groups ranging from Under 8 to Under 14 participated in this study (Table 1). Participants´ (teams and players) selection was conducted in accordance with following criteria: (1) teams and players registered at the Porto Football Association championship and (2) teams and players from the same competitive level.

Players participated on average in ~5h of combined soccer-specific training and competitive soccer match per week (2–3 soccer training sessions and one domestic soccer match per week). All players and their tutors were informed about the research procedures, requirements, benefits, and risks; in addition, written informed consent was obtained from parents. The study protocol followed the guidelines stated in the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Sport of Porto University.

Experimental design

A longitudinal study was conducted over a period of 16 weeks (November – March) in the 2014/2015 competitive season. During this period, three soccer matches a week were performed, for a total of 48 matches. These three matches a week were performed always on Sunday in a triangular tournament format (i.e. match 1: team A vs. team B; match 2: A vs. C; match 3: B vs. C), in accordance with the football rules, except match duration (30 min, without breaks) and players´ substitution (not allowed). Each age-group (Under-8, Under-10, Under-12, and Under-14) performed three matches per game format (i.e. three matches in 5v5, three matches in 7v7, three matches in 9v9, and three matches in 11v11). This sequence was maintained for all age-groups. All matches were conducted in the same artificial third generation pitch surface and, with official dimension (length: 100 m, width: 64 m). The pitch size of the other game formats was adjusted using the relative space per player, i.e. reducing the length and width to the number of players proportionally (Silva et al., 2014). The detailed description of the match conditions is presented in Table 2. Matches were proceeded by a planned, standardised warm up of 15 min comprising running activities, SSGs, and stretching. Following this period, the players simulated a match during two periods of 2 min, interspersed by 1 min of passive recovery. The coaches used a subjective skill assessment of each player to distribute respective teams in a balanced shape. The goalkeepers participated in the matches but were excluded from the analysis.

Table 1. Description of player subsamples.

	U8 (n = 53)	U10 (n = 44)	U12 (n = 41)	U14 (n = 59)	F	P	Post hoc (Bonferroni)
Age (Y)	6.94 ± 0.72	8.52 ± 0.66	11.24 ± 0.44	13.46 ± 0.50	1282.65	<0.001	a,b,c,d
Height (cm)	125.36 ± 6.04	134.57 ± 6.85	146.80 ± 6.49	159.16 ± 7.78	250.13	<0.001	a,b,c,d
Weight (kg)	27.16 ± 5.75	34.70 ± 7.49	41.57 ± 7.47	49.89 ± 8.89	91.02	<0.001	a,b,c,d
Body-mass (kg/m^2)	17.37 ± 3.92	18.93 ± 2.87	19.11 ± 1.78	19.51 ± 1.68	6.33	<0.001	a
Experience (y)	2.06 ± 0.86	3.04 ± 0.91	3.58 ± 1.46	3.68 ± 1.19	23.01	<0.001	a,e

Significant differences are identified as (a) U8 vs. U10; U8 vs. U12; U8 vs. U14, (b) U10 vs. U8; U10 vs. U12; U10 vs. U14, (c) U12 vs. U8; U12 vs. U10; U12 vs. U14, (d) U14 vs. U8; U14 vs. U10; U14 vs. U12, (e) U10 vs. U14. Abbreviations: U8, under 8; U10, under 10; U12, under 12; U14, under 14; a.u., arbitrary unit.

Table 2. Description of match conditions.

	Match Configuration			
Game formats	5v5	7v7	9v9	11v11
Game duration (min)	30 min	30 min	30 min	30 min
Pitch size (length × width)	45.5 × 29 m	64 × 41 m	82 × 52 m	100 × 64 m
Pitch ratio per player (m^2)	1:132	1:187	1:237	1:291
Tactical structure	1–1–2–1	1-2-3–1	1–3-4–1	1–4-3–3
Playing positions	1GK+1DF+2MD+1FW	1GK+2DF+3MD +1FW	1GK+3DF+4MD +1FW	1GK+4DF+3MD +3FW
Goals size (height × width)	2 × 6 m	2 × 6 m	2 × 6 m	2.44 × 7.32 m

Note: Playing positions categories: GK = Goalkeeper; DF = Defender; MD = Midfielder; FW = Forward.

All soccer matches were performed between 9 and 11 a.m., under similar environmental conditions (temperature 10–16°C, relative humidity 49–62%). This protocol was previously sent to the teams. The players were previously informed about the procedures they should adopt.

Data collection

A GPS that captured the spatial-temporal data with a sampling frequency of 10 Hz (Qstarz, model: BT-Q1000eX) was used. The GPS was placed on the upper back of the player (using an appropriate harness). The reliability of similar type of devices has been well documented in the literature (Nicolella, Torres-Ronda, Saylor, & Schelling, 2018; Silva et al., 2016, 2015). Each game format was calibrated with the coordinates of four GPS devices stationed in each corner of the pitch for approximately 4 min. The absolute coordinates of each corner were calculated as the median of the recorded time series, providing robust measurements to typical fluctuations of the GPS signals. These absolute positions were also used to define the reference Cartesian coordinate systems for each game format, with its origin placed at the pitch centre. GPS longitudinal and latitudinal (spherical) coordinates were converted into Cartesian coordinates with the Haversine formula (Sinnott, 1984). Fluctuations in players positions were reduced using a moving average filter with a time scale of (.2 s) and data resampling was employed to synchronise the time series of all players within each match condition (Silva et al., 2015). MatLab software (R2014a, Mathworks Inc., USA) was used to process and analyse the data.

Data analysis

Position data – longitudinal (x-) and latitudinal (y-) coordinates – obtained from GPS devices were used to calculate the match-running variables. Activity ranges selected were adapted from previous studies (Buchheit et al., 2010) as follows: (1) low-intensity running (LIR; running speed <13.0 km.h^{-1}), (2) HIR (running speed from 13.1 to 16 km.h^{-1}), (3) VHIR (running speed from 16.1 to 19 km.h^{-1}), (4) sprinting (SP;

running speed > 19.1 km.h^{-1}), (5) total distance covered (TD). Very high-intensity activities (VHIA) were also calculated as VHIR plus SP.

Statistical analysis

Results are expressed as means ± standard deviations (SD). The assumptions of normality of the data were checked using the Kolmogorov-Smirnov test (along with the coefficients of skewness and kurtosis and performing the visual analysis of box-plots, normal q-q plots, and histograms). Dependent variables (i.e. match-running activities) were analysed using a two-way analysis of variance (ANOVA) with repeated measures, where the game formats (5v5, 7v7, 9v9, and 11v11), age-groups (U8, U10, U12, and U14), and playing positions (defenders, midfielders, and forwards) were the within-participant and between-participant factors, respectively. Mauchly´s test of sphericity was performed on all data to verify any violations of sphericity, which were corrected through the Greenhouse-Geisser adjustment (Bathke, Schabenberger, Tobias, & Madden, 2009). Effect sizes were reported as partial eta squared (η^2) obtained with the ANOVAs, following Cohen´s guidelines (15): (i) $0.01 \leq \eta^2 < 0.06$ – small effect; (ii) $0.06 \leq \eta^2 < 0.14$ – moderate effect; and (iii) $\eta^2 \geq 0.14$ – large effect. Post hoc analysis was followed up using the Bonferroni adjustment. All statistical analyses were carried out using SPSS Statistical Analysis Software (SPSS Inc., Chicago, USA) version 22.0 for windows, with significance level being defined as $p \leq 0.05$.

Results

Age-related running activities accounting for each soccer match condition are detailed in Figure 1. The older players covered significantly greater distance in all running categories (e.g., TD: $\eta^2 = 0.32$, $p < 0.001$; LIR: $\eta^2 = 0.09$, $p < 0.001$; HIR: $\eta^2 = 0.25$, $p < 0.001$; VHIR: $\eta^2 = 0.34$, $p < 0.001$; VHIA: $\eta^2 = 0.42$, $p < 0.001$; and SP: $\eta^2 = 0.41$, $p < 0.001$) than young players. Nevertheless, such differences were more expressive in the VHIA and SP categories, as suggested in Figure 1.

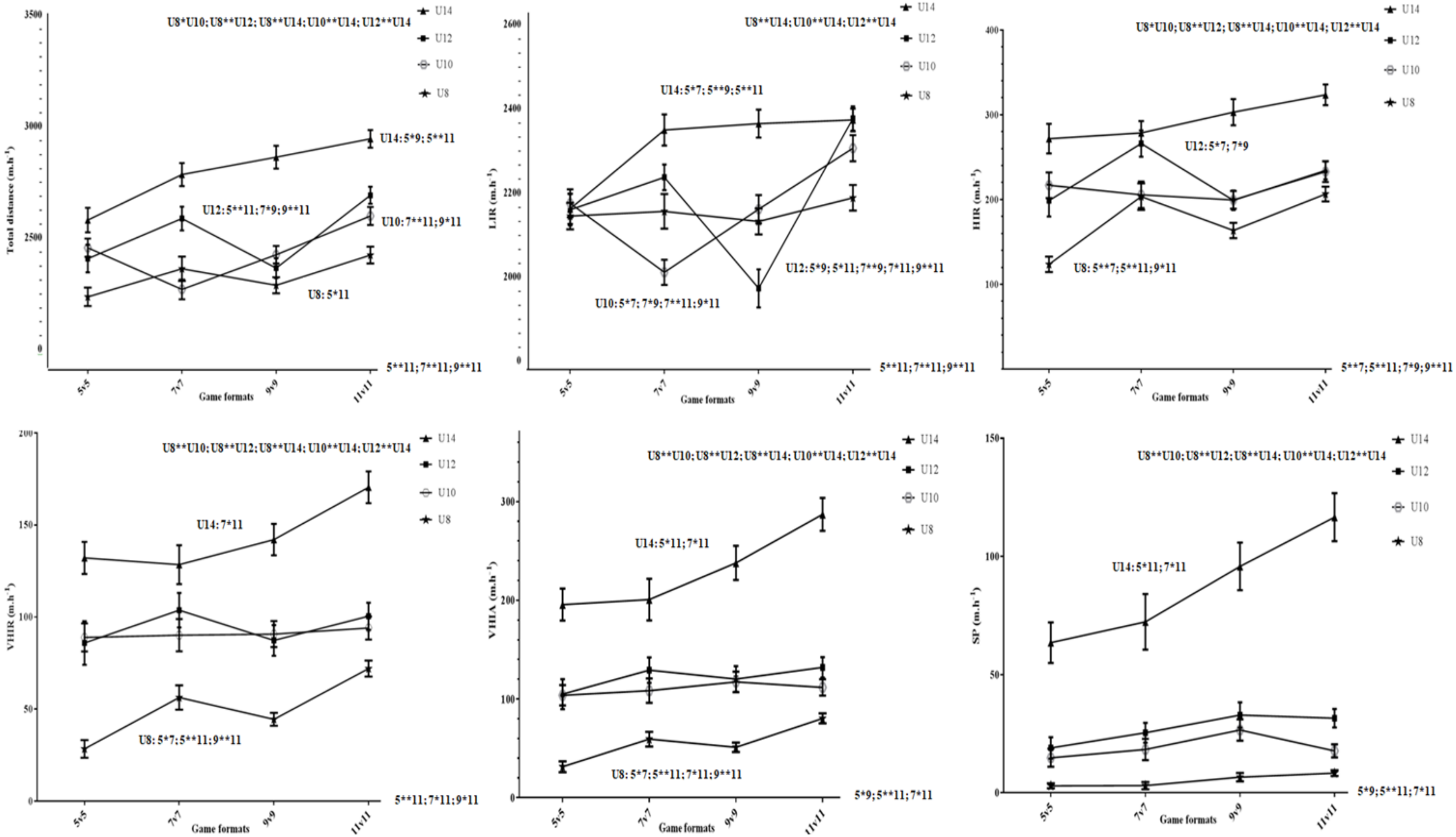

Figure 1. Match-running performance according to the age-group and game format.
Note: Running activity categories: total distance covered (TD), low-intensity running (LIR; running speed < 13.0 km.h^{-1}), high-intensity running (HIR; running speed from 13.1 to 16 km.h^{-1}), very high-intensity running (VHIR; running speed from 16.1 to 19 km.h^{-1}) and sprinting (SP; running speed > 19.1 km.h^{-1}). Very high-intensity activities (VHIA) = VHIR + SP. Significant differences marked in 3 contexts: between age-groups; between game formats; and between game formats per each specific age-group (p<0.05)* and (p<0.001)**

The running activities related with game formats also revealed significant differences in all categories (e.g., TD: $\eta^2 = 0.44$, $p < 0.001$; LIR: $\eta^2 = 0.41$, $p < 0.001$; HIR: $\eta^2 = 0.25$, $p < 0.001$; VHIR: $\eta^2 = 0.17$, $p < 0.001$; VHIA: $\eta^2 = 0.16$, $p < 0.001$; and SP: $\eta^2 = 0.13$, $p < 0.001$). The distance covered in all running categories have been significantly higher on 11v11 than 5v5, 7v7, and 9v9 game formats ($p < 0.001$). The main differences are shown in Figure 1.

Players´ positional functions-related running activities accounting for each age-group are detailed in Figure 2. There was a significant difference in all running activities between the players´ positional functions related with the age-group ($p < 0.001$). Defenders covered lowest TD and HIR than midfielders and forwards in all age-groups ($p < 0.001$) while midfielders covered highest TD and LIR than defenders and forwards in all age-groups ($p < 0.001$). Forwards covered highest VHIR, VHIA, and SP than midfielders and defenders, especially in U14 age-group.

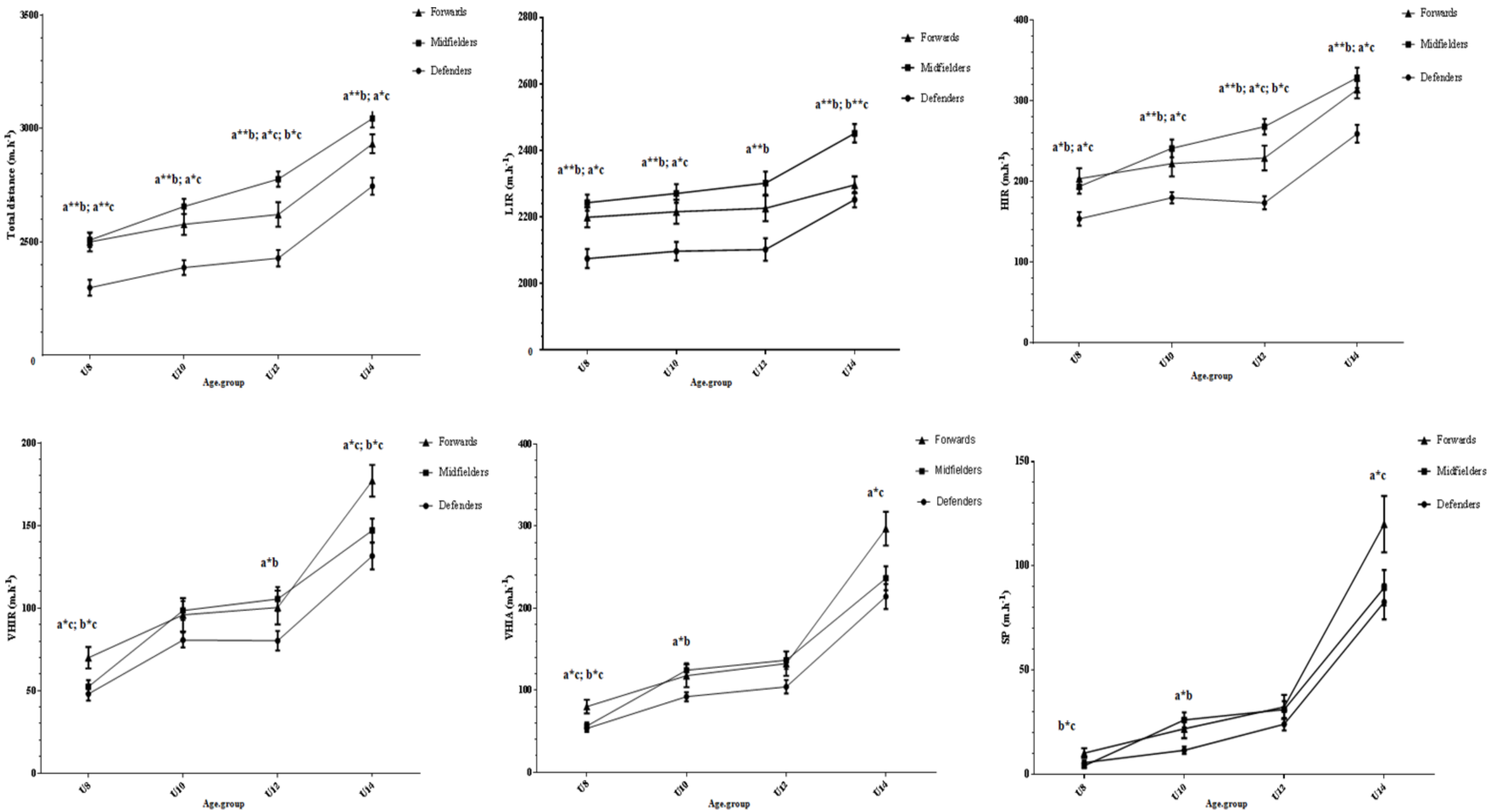

Figure 2. Match-running performance according to the playing positions in each age-group.

Note: Running activity categories: total distance covered (TD), low-intensity running (LIR; running speed < 13.0 km.h^{-1}), high-intensity running (HIR; running speed from 13.1 to 16 km.h^{-1}), very high-intensity running (VHIR; running speed from 16.1 to 19 km.h^{-1}) and sprinting (SP; running speed > 19.1 km.h^{-1}). Very high-intensity activities (VHIA) = VHIR + SP. Playing positions: a = Defenders; b = Midfielders; c = Fowards. Significant differences between conditions: (p<0.05)* and (p<0.001)**.

Players´ positional functions-related running activities accounting for each game format are detailed in Figure 3. There was a significant difference in all running activities between the players´ positional functions related with the game formats ($p < 0.001$). Regardless of the game format, defenders covered lowest TD, LIR, HIR, and VHIR while midfielders covered highest TD and HIR ($p < 0.001$). Forwards covered highest VHIR, VHIA, and SP in 11v11 game format ($p < 0.001$).

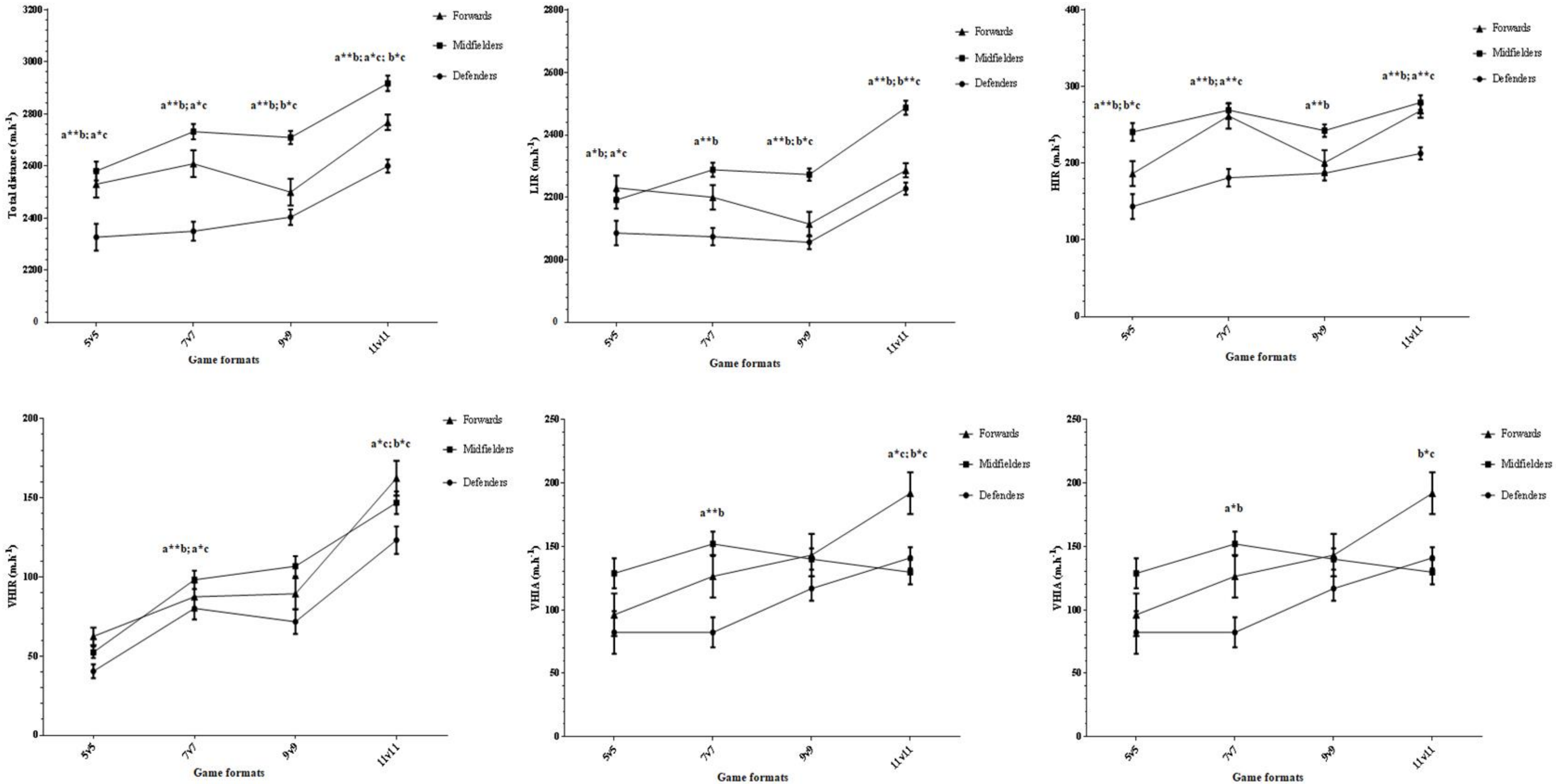

Figure 3. Match-running performance according to the playing positions in each game format. Note: Running activity categories: total distance covered (TD), low-intensity running (LIR; running speed < 13.0 km.h^{-1}), high-intensity running (HIR; running speed from 13.1 to 16 km.h^{-1}), very high-intensity running (VHIR; running speed from 16.1 to 19 km.h^{-1}) and sprinting (SP; running speed > 19.1 km.h^{-1}). Very high-intensity activities (VHIA) = VHIR + SP. Playing positions: a = Defenders; b = Midfielders; c = Fowards. Significant differences between conditions: (p<0.05)* and (p<0.001)**.

Discussion

The aim of this study was to determine whether the game format, age group and playing positions influences match-running performance of non-elite youth soccer players during soccer match. To our knowledge, this is the first study that combines the most used game formats along players´ developmental stages (i.e. 5v5, 7v7, 9v9, and 11v11 game formats) with a wider age-groups range (i.e. from U8 to U14).

The main findings of the present study confirmed the hypothesis that the oldest age-groups cover a significantly highest distance in each match-running category than youngest groups, with main differences observed between the extreme age-groups. This trend was also verified with elite young players (Buchheit et al., 2010; Goto et al., 2015b; Harley et al., 2010) suggesting that players´ level does not produce changes in the mentioned trend. Specifically, present study demonstrated that non-elite young players covered a total distance of ~2.4 km.h^{-1} for the U8 age-group, ~2.5 km.h^{-1} for U10, ~2.6 km.h^{-1} for U12, and ~2.9 km.h^{-1} for the U14 age-group, which represents an increase of ~ 21% between U8 and U14 age-group. The distance covered by the players in our study was lower than reported for elite players from England, as can see in the study conducted by (Goto et al., 2015a) where the U10 elite players covered a distance of ~4.7 Km.h^{-1} or in study by (Harley et al., 2010) where the U12 elite players covered a distance of ~5.9 Km.h^{-1} and U14 covered ~5.7 Km.h^{-1}. Such differences can be justified based on the participants´ characteristics and the experimental design used in the respective studies, which implies caution when comparing the results. Similarly, the magnitude of “age-group effect” was highest for the VHIR activity and sprinting than the lowest-intensity running activity (η^2 > 0.41–0.42 vs. 0.09 for VHIR and SP vs. LIR, respectively) suggesting that the age-group was determinant in the capacity to produce running activity at higher intensity thresholds. Present results are similar to those obtained by (Buchheit et al., 2010), which examined match running performance in a wide age range of young elite players (U13 to U18). In this context, it may be suggested that the oldest players have greater physical capacities to produce running activity at speeds above > 19.1 km.h^{-1} than their younger counterparts, regardless of the players´ level, match duration, and pitch dimensions, probably due to the influence of maturation on maximal effort activity as well as the differences in height and weight among age-groups.

The current study also demonstrated that players´ match-running performance was influenced by the game format, confirming the hypothesis that the game formats with more players have a significantly greater effect on match-running performance than game formats with fewer players. To be precise, the players´ running activity was also significantly higher on soccer matches performed in 11v11 game format compared to 7v7 in TD, LIR, VHIR, VHIA, and SP categories, as well as in 11v11 game format compared to 9v9 in TD, LIR, HIR, and VHIR categories, respectively. On the other hand, it has been shown that the players´ match-running performance was similar between intermediates game formats (5v7, and 7v9, respectively), suggesting that there is a trend for mean values of players´ running activity to be higher between extreme formats. These findings are consistent with a previous study of (Randers et al.,2014). The mentioned study suggested that total distance covered by the players was similar between 5v5 and 8v8 but lower in 8v8 than 11v11 condition as well as the distance covered at highest running speeds was lower in 5v5 than in 8v8 condition and differences between 8v8 and 11v11 in distance covered were observed in all speed categories. Current study also demonstrated that magnitude of "game-format effect" was highest for total distance and the distance covered at LIR than for theVHIR and SP (η^2 > 0.41–0.44 for TD and LIR vs. 0.13–0.17 for VHIR and SP, respectively), suggesting that as the running activity at high intensity increases the effect of game format decreases. Such hypothesis may result from the players´ anaerobic capacity, because the previously mentioned regime is more demanding from physical viewpoint, impairing, in this way, the players´ ability to perform HIA systematically. These data suggest that young non-elite players are not yet prepared to develop high-intensity activity on an ongoing basis, reflecting, therefore, a slower and more predictable style of play. Furthermore, we understand that the game formats with less players can contribute to reduce this effect, that is, the 5v5 and 7v7 formats can promote a game style faster, in which players contact the ball regularly and for longer, which contributes to their physical, technical, and cognitive development.

Although speculative, it can be supposed that older players, due to their greater levels of experience, already accustomed to the 11v11 game format tend, on one hand, to show greater variety of behaviours and movements (tactical perspective) and, on the other hand, to have a greater ability to perform activity repeatedly (physical perspective). At the same time, current study also detected that the match-running performance of U8 and U12 age-groups decreases in all running categories (except sprinting) when they transited from the 7v7 to 9v9 game format. Probably, this trend was a result from the players´ inadaptability to the 9v9 format because in Portugal, the 9v9 format is still little used; furthermore, the study participants experienced this format for the first time, which may have induced physical and tactical constraints.

Match analyses have demonstrated that match-running performance of U8 to U14 non-elite players was significantly influenced by playing positions. To be precise, defenders covered lowest distance in TD, LIR, HIR, VHIR, and VHIA categories in all age-groups while midfielders covered highest distance in TD and LIR categories, respectively. This trend was also verified with (U13 to U18) elite players (Buchheit et al., 2010; Mohr, Krustrup, & Bangsbo, 2003), which suggests that the players´ level is not a discriminating factor of the effect-related to playing positions. A curious fact occurred with U14 and U8 age-groups, where forwards covered a considerably greater distance in the VHIR, VHIA, and SP categories than players in the other positions. This outcome can be a consequence of their continuous attempt to create unpredictable situations and surprise the opponent defensive players (i.e. players´ characteristics) as well as the continuous movement performed to correspond to the game requests promoted by the teammates (i.e. game style of team).

As the current study evaluated the effect of playing positions on a wide range of age-groups and game formats, we can argue that provided results expanded the previous findings of (Buchheit et al., 2010; Dellal, Moalla, Chamari, & Wong, 2010; Dellal et al., 2012; Gonçalves, Figueira, Maçãs, & Sampaio, 2014; Mohr et al., 2003). Our results showed that there was a significant difference in running activities between the playing positions-related with the game formats. To be precise, the defenders covered the lowest distance in TD, LIR, HIR, and VHIR categories in soccer matches performed in 5v5, 7v7, 9v9, and 11v11 formats; whereas, the midfielders covered the highest distance in TD and HIR categories in the mentioned formats. Moreover, the forwards covered highest distance in VHIR, VHIA, and SP categories in 11v11 format. While we are not aware of any comparable data in the literature, this trend is in line with the study conducted by (Dellal et al., 2012), which examined the effects of common rule changes on physical demands for elite adult soccer players in five playing positions during various 4-min SSGs in comparison to 11v11 condition. From the analysis of distance covered by the defenders, midfielders, and forwards in all running categories during soccer matches performed in 5v5, 7v7, 9v9, and 11v11 formats, our research demonstrated another interesting pattern, i.e. in TD, LIR, and HIR running categories, was detected differences between the playing positions in the four game formats; whereas in VHIR, VHIA, and SP categories, the differences between the playing positions were only verified in 7v7 and 11v11 game formats, as can be seen in Figure 3. From these data, it can be supposed that the distribution of the efforts developed in very high intensity by each playing position is similar during the soccer matches performed in 5v5 and 9v9 formats. Probably, the relationship between the players´ number and the pitch size of the 5v5 and 9v9 formats promotes a structured game style from tactical viewpoint, reflecting; on one hand, a balanced distribution of the players´ tactical tasks; on the other, a lower intensity in running activities performed by all playing positions.

Conclusions

We recognise that the most accurate knowledge about physical adaptations promoted by each game format, age-group, and playing position may contribute, on one hand, for the coaches to use the most appropriate tools in the young players training process and optimise their performance; on the other, it can help the coaches and national governing bodies to implement adequate practice conditions in which the requirements of the game are appropriate in relation to the age and characteristics of the young soccer players. The main practical applications, for coaches and strength-conditioning professionals, to be drawn from this study is that match-running performance of non-elite young players is significantly influenced by age, in which oldest players (U14) covered greater distance in all categories compared to their younger counterparts. In this context, players of 8 and 10 years should not be considered adults in miniature, which implies that the training sessions and soccer-match conditions must be adapted to their physical abilities.

At the same time, data of present study also suggest a significant effect of game formats upon the distance covered by the players in all match-running categories. Specifically, players covered a significantly higher distance in all match-running categories in the 11v11 format compared to 5v5 and 7v7 formats. Such differences were not as marked between the 9v9 and 11v11 formats, especially in very-high intensity and sprinting regimes. Thus, as the 9v9 game format is still seen with reluctance in some European countries, such as in Portugal, and for this reason is little and/or nothing used, we suggest that the 9v9 game format should be used in youth competitions because, on the one hand, will increase the players´ practice experiences during their development process and, on the other, will express a progressive and balanced transition until the 11v11 format.

Finally, match analyses have demonstrated that match-running performance is position dependent. These insights can provide the opportunity for coaches to maximise the efficiency of their training sessions, providing relevant implications to improve the specific physical behaviour of players according their tactical role in the soccer-match.

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Study V.

Submited

Brito, A., & Garganta, J. (2018). The influence of the 5v5, 7v7, 9v9 and 11v11 game formats on the positioning and displacement of young soccer players during match-play. *Journal of Human Kinetics.*

The influence of the 5v5, 7v7, 9v9 and 11v11 game formats on the positioning and displacement of young soccer players during match-play

Abstract

Present study aimed to analyse the effect of game format and age-group on positioning and displacement of soccer players (age ranging from 6.94 ± 0.7 to 13.46 ± 0.5 years; height ranging from 125.36 ± 6.04 to 159.16 ± 7.78 cm; weight ranging from 27.16 ± 5.75 to 49.89 ± 8.89 kgf). Linear and non-linear analyses were used to capture the spatial distribution variability and relative positioning of the players during soccer matches. Variables were assessed using global positioning system technology. Results suggest significant effect of the game formats in spatial distribution variability ($\eta^2 = 0.142$, $p < 0.001$) and relative positioning ($\eta^2 = 0.926$; $p < 0.001$) of the players. The variability decreased as game format increased and mean covered area increased as game format increased. There also were significant effect of the age-group in spatial distribution variability ($\eta^2 = 0.120$, $p < 0.001$) and relative positioning ($\eta^2 = 0.405$; $p < 0.001$). The U10 age-group presented significantly higher values than other age-groups ($p < 0.001$). These findings can provide an opportunity for coaches and governmental bodies to maximise the efficiency of the soccer matches conditions.

Keywords: movement variability; spatial distribution maps; performance analysis; game formats; team sport

Introduction

Most European countries are seeking to optimise the use of game formats to perform the official youth leagues soccer matches along the development stages of players. These stages express the process of maturation, learning, training and practice of the young players through the development of specific skills either during the training units or soccer matches (Gagné, 2000; Vaeyens et al., 2008). To provide suitable conditions of practice during official soccer matches, variables such as pitch size, number of players and duration of the match must be adapted to the age and characteristics of the participants (Lapresa et al., 2009; Capranica et al., 2001). The strategy which is being used by most European countries is to progressively increase the number of players and the pitch size up to the 11v11 game format. For instance, from Under-8 (U8) up to Under-14 (U14) age-groups, the most widely used game formats are being the 5v5, 7v7, 9v9 and 11v11 respectively (Brito et al., 2017), Beyond this problem, it´s also common to find (e.g. in Portugal) young´s with12 and 13 years old to perform official soccer matches upon a 11v11 game format with pitch dimensions with maximum of length and width, which is not suitable from pedagogical point of view for the age and ability of the players (Lapresa et al., 2009; Capranica et al., 2001).

Previous study conducted on the early stages of the developmental process of the players proposed the use of 3v3 instead of 5v5 condition for the U8 age-group, because in the 5v5 condition, the U8 used little playing space; showed little variability of movement; and presented low number of contacts with the ball (Lapresa et al., 2010). However, when analysing and comparing the characteristics of attack process during soccer matches performed in the 7v7 and 8v8 condition with players of under 8-10 age-groups (Lapresa et al., 2009) did not find significant differences between both conditions. Another study of (Capranica et al., 2001) with 11-year-old players suggested advantages in the 7v7 compared to the 11v11 game condition. The authors concluded that in the game 7v7 the total number of passes was superior, and the total number of ball losses was lower compared to 11v11 condition. With the purpose to analyse and compare the characteristics of attack process during soccer matches performed in the 9v9 and 11v11 condition Lapresa et al. (2006) suggested that 9v9 is a valuable alternative for the under 10-12 age-groups because reduces the difficulties of adapting to the 11v11 condition. More recently, Lapresa et al. (2013) analysed the ball circulation patterns in games 7v7, 9v9 and 11v11 condition concluding that the game of 7v7 and 9v9 facilitate the development of gaming space management skills, compared with 11v11 condition. Despite this information, authors such as Lapresa et al. (2006) that the transition from the 7v7 to 11v11 condition can create a mismatch between the game occurrences and the real possibilities of young soccer players, especially in the transition from the U12 to U14 age-group. Accordingly, it is necessary to improve the knowledge upon the type of adaptations and/or constraints induced by the game formats that are being used in competition at the different age-groups (Casamichana and Castellano, 2010; Castellano et al., 2016). This knowledge, on one hand is a step forward for the coaches promote the acquisition of individual and collective behaviours of the players and on the other hand contributes for the governmental bodies to provide suitable practice conditions for the development of young players.

The nature of a soccer match is dynamic and complex reflecting the players´ efforts to adapt and overcome to structural, environmental and functional game variables, such as pitch size, number of players, climate, ball trajectories, positioning and displacement of teammates (Bangsbo, 1994; Bradley et al., 2011; Gréhaigne et al., 2011). In this complex environment, players express behavioural variability, inherent of the actions, positioning and displacement promoted to respond to the game requirements (Garganta, 2008). Such behaviours are susceptible to display relevant information that can contribute to describe the tactical performance of players and teams (Ric et al., 2017; Sampaio and Maçãs, 2012). For instance, Aguiar et al. (2015) demonstrated that the addition of players to the team induces a higher level of collective organization and optimizes the space occupation of the players. A study conducted by Silva et al. (2015) also suggested that when increasing the relative space per player by reducing the number of players, the players´ positioning tends to be more irregular whereas when the field dimension increases the players´ positioning becomes more regular. In this context, analysis of positional data in soccer allows to describe the spatial distribution of the players during the matches improving therefore the understanding of tactical-related constraints on the behavioural dynamics of players (Ric et al., 2017). Thus, one of the main challenges for researchers is to find suitable tools that allows to analyse the movement and displacements patterns of the players during soccer matches with the purpose to characterize the game profile from a tactical perspective (Aguiar et al., 2015).

Global positioning systems (GPS) are an important tool to collect data that contribute for relevant insights on the analysis of soccer player´s performance either in training or soccer match (Cummins et al., 2013). Portable GPS devices provide spatial-temporal data with the reasonable accuracy to tracking movement variability indicators, such as the positioning, displacements and trajectories of the players in the pitch (Coutts and Duffield, 2010; Gray et al., 2010). The movement variability of the players is omnipresent and unavoidable during a soccer match due to the distinct constraints that shape each individual´s behaviour during the game (Davids et al., 2003). Therefore, the mensuration of this variability through positional data of the players can be used to access performance indicators that allow to understand and describe the dynamic and situational character of the game events reflected in the pitch from a tactical point of view (Couceiro et al., 2014; Memmert et al., 2017; Silva et al., 2014a). For a better understanding of game styles see (Fernandez-Navarro et al., 2016).

To quantify the variability of spatial-temporal data, the range, the standard deviation or the coefficient of variation can be used together with measures of central tendency (mean, median and mode). However, these linear measures are being complemented with more sophisticated analysis, such as the one based on entropy values obtained from player´s spatial distribution maps (Couceiro et al., 2014; Siegle et al., 2008; Silva et al., 2014a; Silva et al., 2015). The entropy, originally described by Shannon (1948), is a non-linear measure that can be used to represent the uncertainty of locating the player in a specific region of the soccer pitch (Silva et al., 2014a). Normalized entropy ranges from 0 to 1, where values near to 0 express highly predicted positions of the players on the pitch while values near to 1 reflect highly variable or unpredicted positions (Silva et al., 2014a). Thus, variability can be interpreted as a result of the player´s effort to adapt to unexpected events and specific game constraints as well as the player´s versatility on the performance of his tactical playing positioning. In addition, the heat maps also reflect the spatial distribution of the players over the pitch, considering the time spent by each player at a certain position which is an interesting framework to analyze the variability of players´ movement (Couceiro et al., 2014). Another sophisticated method that are being used it is the relative positioning of the players in the pitch, centred on their average positional coordinates, with axes corresponding to the displacements´ standard deviations in the longitudinal and lateral directions of the soccer pitch, providing additional information concerning the tactical behavior of the players and teams (Silva et al., 2014b; Yue et al., 2008). For instance, a study by Silva et al. (2014b) has analysed the distribution of the movement coordinates of young soccer players (under-19), divided into two groups according to skill level (national-level and regional-level), suggesting that the players of national-level express differentiated distributions on longitudinal direction while the players of regional-level present very similar longitudinal coordinates of the pitch, only varying their positioning along the lateral direction. Additionally, a study conducted by (Yue et al., 2008) demonstrated that players which play in the more advanced areas of the pitch (forwards and wings) present movements of greater amplitude in comparison with players who play in the lower back (midfielders, and central-defenders and fullbacks).

Despite the aforementioned studies, to our knowledge, we don´t know any work which explored the effect of game format and age-group upon variability of positioning and displacement of young soccer players during match play. The lack of scientific evidence about the effect of these variables on performance of young players, reflects many doubts about whether the game formats that are being used in the youth championships are adapted to the characteristics and capacity of the participants (Arana et al., 2004; Tessitore et al., 2012). Therefore, the purpose of this study is: (1) to examine the positioning and displacements of young players associated with four game formats (5v5, 7v7, 9v9, and 11v11) when the relative space per player was kept constant; (2) to assess the positioning and displacement of youth soccer players in the U8 to U14 age-groups. It was hypothesized that the game formats and the age-group induce differences in positioning and displacement of the players during soccer matches.

Methods

Participants

One hundred and ninety-seven non-elite young soccer players of 4 different age-groups participated in this study (Table 1). The selected participants (teams and players) were of the same league and had the same competitive level.

Table 1. Description of player sub samples

	U8 (*n* = 53)	U10 (*n* = 44)	U12 (*n* = 41)	U14 (*n* = 59)	*F*	*P*	Post hoc (Bonferroni)
Age (Y)	6.94±0.72	8.52±0.66	11.24±0.44	13.46±0.50	1282.65	< 0.001	a,b,c,d
Height (m)	125.36±6.04	134.57±6.85	146.80±6.49	159.16±7.78	250.13	< 0.001	a,b,c,d
Weight (Kg)	27.16±5.75	34.70±7.49	41.57±7.47	49.89±8.89	91,02	< 0.001	a,b,c,d
Body-mass (a.u)	17.37±3.92	18.93±2.87	19.11±1.78	19.51±1.68	6.33	< 0.001	a
Experience (y)	2.06±0.86	3.04±0.91	3.58±1.46	3.68±1.19	23.01	< 0.001	a,e

Significant differences are identified as (a) U8 vs U10; U8 vs U12; U8 vs U14, (b) U10 vs U8; U10 vs U12; U10 vs U14, (c) U12 vs U8; U12 vs U10; U12 vs U14, (d) U14 vs U8; U14 vs U10; U14 vs U12, (e) U10 vs U14. Abreviations: U8, under 8; U10, under 10; U12, under 12; U14, uder 14; a.u., arbitrary unit.

Players participated on average in ~ 5h of combined soccer-specific training and competitive soccer match per week, 3 soccer training sessions and 1 domestic soccer match per week. All players and their tutors were informed about the research procedures, requirements, benefits and risks, and written informed consent was obtained from parents. The study protocol followed the guidelines stated in the Declaration of Helsinki and was approved by the Ethics Committee of the Faculty of Sport of Porto University.

Measures

The positional data were used to calculate: (1) players´ spatial distribution variability, assessed by measuring the entropy of individual spatial distribution maps (Shannon, 1948; Silva et al., 2015). These maps were obtained from discretization of the pitch into sectors of 1 m^2, allowing to calculate the amount of time spent in each sector, normalized to total match duration to produce spatial probability distributions.

In this way, a normalized value of entropy, ranging from 0 to 1, was calculated to quantify the uncertainty of locating each player in a specific location of the pitch. A low entropy value (near zero) indicating a sharply peaked distribution, suggests the player's position can be easily predicted. On the other hand, a high entropy value (near 1) corresponds to an uniform distribution and suggests the player exhibits high spatial distribution variability or that its position is highly variable and unpredictable (Silva et al., 2015). Taking into consideration the participant´s experience, the entropy was also related with team tactical performance. Thus, teams with players with high entropy values were interpreted as using a game style that promoted positional exchanges between players and more diversified tactical functions. On the other hand, teams with players with low entropy values were interpreted as using a game style based on more consistent displacement and more specific tactical functions; (2) the covered area by players in the pitch surface, assessed by measuring the area of ellipses representative of players´ pitch displacement, centred on the average positional coordinates of the players, with axes corresponding to the standard deviation of displacement in the longitudinal and lateral directions of the pitch (Zengyuan et al., 2008). Through elliptic forms we evaluated qualitatively the main directions of the players movements and their distribution and relative positioning on the pitch (Silva et al., 2014b). The ellipse areas were also calculated to provide quantitative information of the space predominantly used by each player during soccer matches.

Design and procedures

A longitudinal study was conducted over a period of 16 weeks (November – March) in the 2014/2015 competitive season. During this period 3 soccer matches a week were performed, for a total of 48 matches. This 3 matches a week were performed always on Sunday in a triangular tournament format (i.e. match 1: team A vs. team B; match 2: A vs. C; match 3: B vs. C), in accordance with the football rules, except match duration (30min, without breaks) and players´ substitution (not allowed). Each age-group (Under-8, Under-10, Under-12, and Under-14) performed 3 matches per game format (i.e. 3 matches in 5v5, 3 matches in 7v7, 3 matches in 9v9, and 3 matches in 11v11). This sequence was maintained for all age-groups. All matches were conducted in the same artificial third-generation pitch surface and, with official dimension (length: 100 m, width: 64 m). The pitch size of the other game formats was adjusted using the relative space per player, i.e. reducing the length and width to the number of players proportionally (Silva et al., 2014a). The detailed description of the match conditions is presented in Table 2. Matches were proceeded by a planned, standardised warm up of fifteen minutes comprising running activities, small-sided games and stretching. Following this period, the players simulated a match during two periods of two minutes, interspersed by one minute of passive recovery. The coaches used a subjective skill assessment of each player to distribute respective teams in a balanced shape. The goalkeepers participated in the matches but were excluded from the analysis. All soccer matches were performed between 9 and 11 a.m., under similar environmental conditions (temperature 10–16°C, relative humidity 49–62%). This protocol was previously sent to the teams. The players were previously informed about the procedures they should adopt.

Table 2. Description of match conditions

	Match Configuration			
Game formats	5v5	7v7	9v9	11v11
Game duration (min)	30 min	30 min	30 min	30 min
Pitch size (length x width)	45.5 x 29 m	64 x 41 m	82 x 52 m	100 x 64 m
Pitch ratio per player (m2)	1:132	1:187	1:237	1:291
Tactical structure	1-1-2-1	1-2-3-1	1-3-4-1	1-4-3-3
Playing positions	1GK+1DF+2MD+1FW	1GK+2DF+3MD+1FW	1GK+3DF+4MD+1FW	1GK+4DF+3MD+3FW
Goals size (height x width)	2 x 6 m	2 x 6 m	2 x 6 m	2.44 x 7.32 m

Note: Playing positions categories: GK=Goalkeeper; DF=Defender; MD= Midfielder; FW=Forward.

A Global Positioning System (GPS) that captured the spatial-temporal data with a sampling frequency of 10 Hz (Qstarz, model: BT-Q1000eX) was used. The GPS was placed on the upper back of the player (using an appropriate harness). The reliability of similar type of devices has been well documented in the literature (Nicolella et al., 2018; Silva et al., 2016; Silva et al., 2015). Each game format was calibrated with the coordinates of four GPS devices stationed in each corner of the pitch for approximately 4 min. The absolute coordinates of each corner were calculated as the median of the recorded time series, providing robust measurements to typical fluctuations of the GPS signals. These absolute positions were also used to define the reference Cartesian coordinate systems for each game format, with its origin placed at the pitch centre. GPS Longitudinal and latitudinal (spherical) coordinates were converted into Cartesian coordinates with the Haversine formula (Sinnott, 1984). Fluctuations in players positions were reduced using a moving average filter with a time scale of (.2 s) and data resampling was employed to synchronise the time series of all players within each match condition (Silva et al., 2015). MatLab software (R2014a, Mathworks Inc., USA) was used to process and analyse the data.

Statistical Analysis

Results are expressed as means ± standard deviations. A two-way analysis of variance (ANOVA) with repeated measures was employed to evaluate the differences in the described variables between each pitch surface. The Mauchly´s test of sphericity was performed on all data to verify any violations of sphericity that were corrected through the Greenhouse-Geisser adjustment (Bathke et al., 2009). Effect sizes were reported as partial eta squared (η^2) obtained with the ANOVAs, following Cohen´s guidelines (Cohen, 1988): (i) $0.01 \leq \eta^2 < 0.06$ – small effect; (ii) $0.06 \leq \eta^2 < 0.14$ – moderate effect; and (iii) $\eta^2 \geq 0.14$ – large effect. *Post hoc* analysis was performed using the Bonferroni adjustment. All statistical analyses were carried out using SPSS Statistical Analysis Software (SPSS Inc., Chicago, USA) version 22.0 for Windows.

Results

Spatial distribution

The entropy values decrease as game format increase (Figure 1). ANOVAs yielded a main effect for game format $F(9.453) = 8.357$; $p < 0.001$, $\eta^2 = 0.142$; $\pi = 0.863$.

Post-hoc analysis revealed significant differences between all game formats ($p<0.001$ in all comparisons).

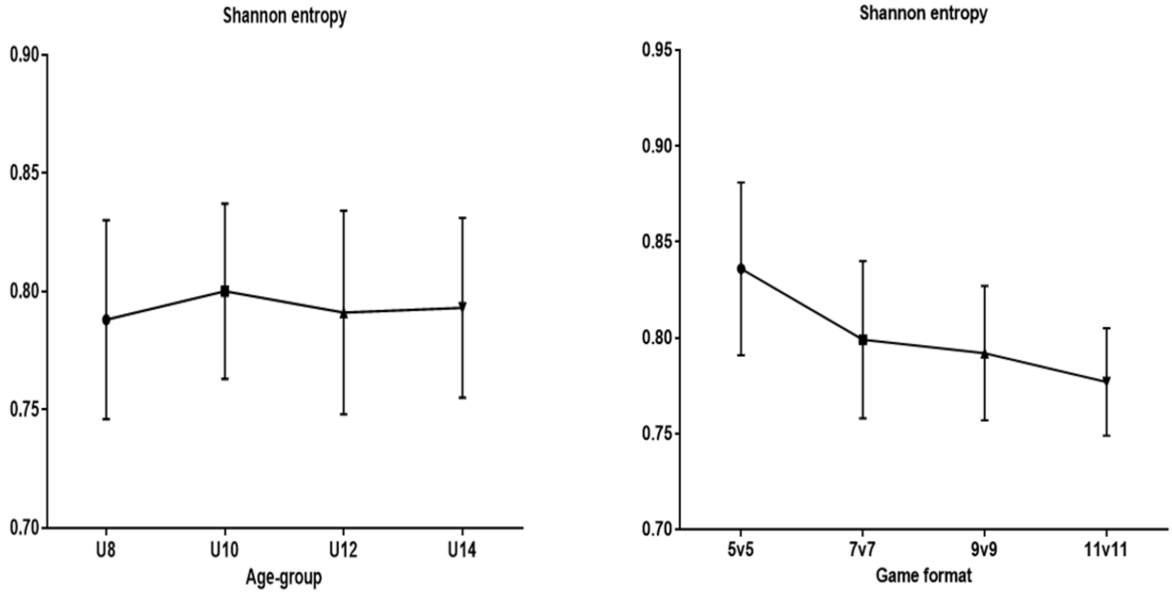

Figure 1. Mean values for Shannon entropy of the players on each age-group and game format. Error bars represent standard deviation.

In relation to the age-group the entropy values were higher on the U10 age-group compared to the other age-groups (Figure 1). ANOVAs yielded a main effect for age-group $F(3.453) = 20.647$; $p < 0.001$, $\eta^2 = 0.120$; $\pi = 1.000$.

Post-hoc analysis revealed significant differences between U10 age-group and all other age-groups (p<0.001).

Figure 2 presents an example of spatial distribution maps of players for each game format, highlighting higher variability in spatial distribution on the 5v5 and 7v7 game formats.

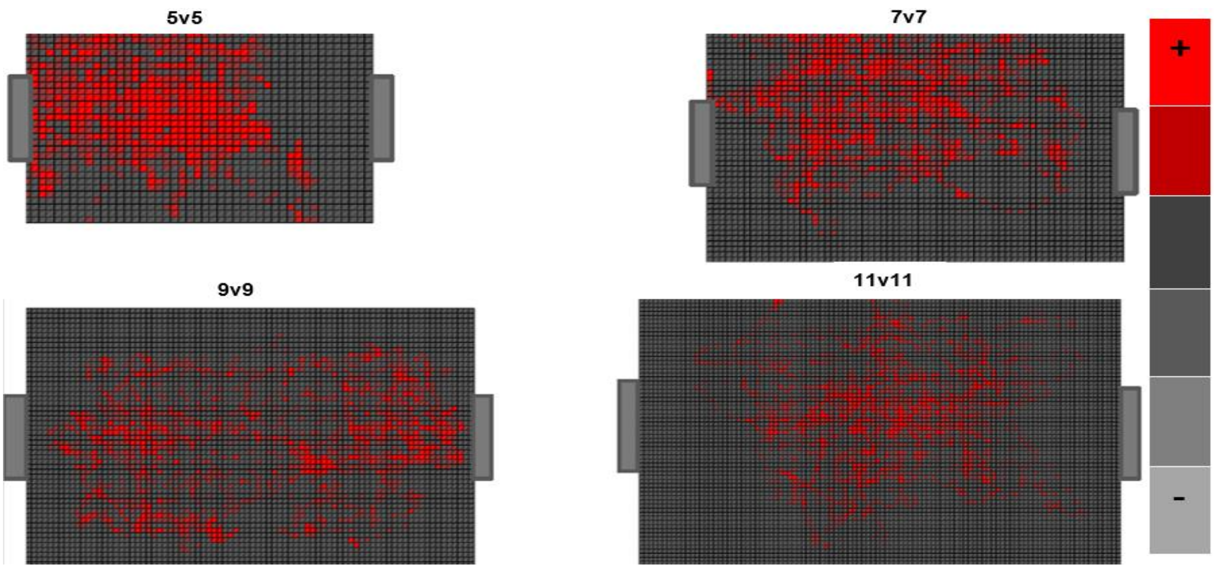

Figure 2. Exemplar spatial distribution maps of players from each game format.

Relative positioning

Figure 3 illustrates the ellipse areas, centred on the average of players´ positional coordinates, with semi-axes that correspond to the standard deviation of displacement in the longitudinal and lateral directions on each game format. The elliptic forms show less eccentricity and/or greater overlap in the following configurations (U8 <> 5v5; U10 <> 7v7; U12 <> 9v9; and U14 <> 11v11).

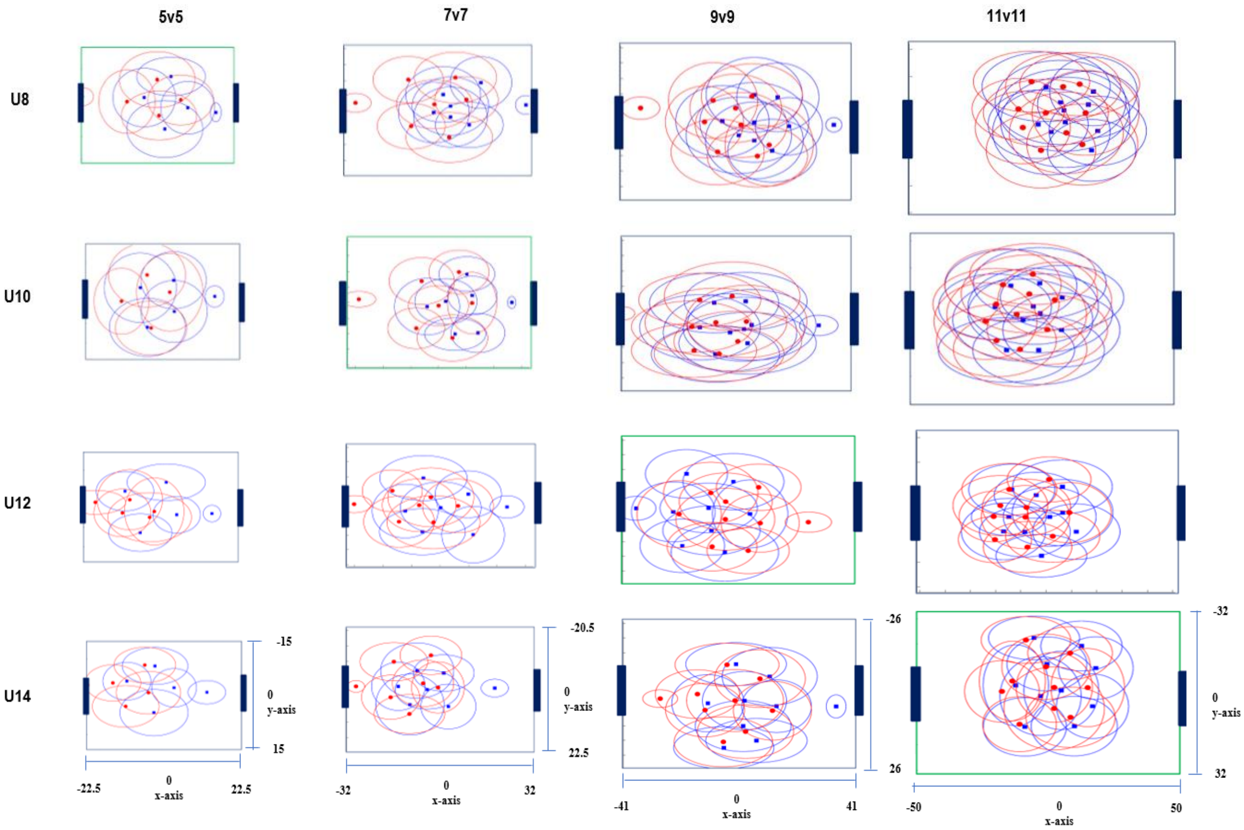

Figure 3. Players´ elliptical areas for each age-group on each game format. Blue and red ellipses depict the players' major displacement of each team, respectively. Lateral (y-axis) and longitudinal (x-axis) axes depict pitch coordinates.

The mean covered area decrease as game format increase (Figure 1). ANOVAs yielded a main effect for game format $F(3.151) = 625.72$; $p < 0.001$, $\eta^2 = 0.926$; $\pi = 0.863$.

Post-hoc analysis revealed significant differences between all game formats (p<0.001 in all comparisons).

ANOVAs yielded a main effect for age-group $F(3.405) = 102.6$; $p < 0.001$, $\eta^2 = 0.405$; $\pi = 1.000$.

Post-hoc analysis revealed significant differences between the U8 and all other age-groups as well as between U10 and all other groups (p<0.001). No differences were found between U12 and U14.

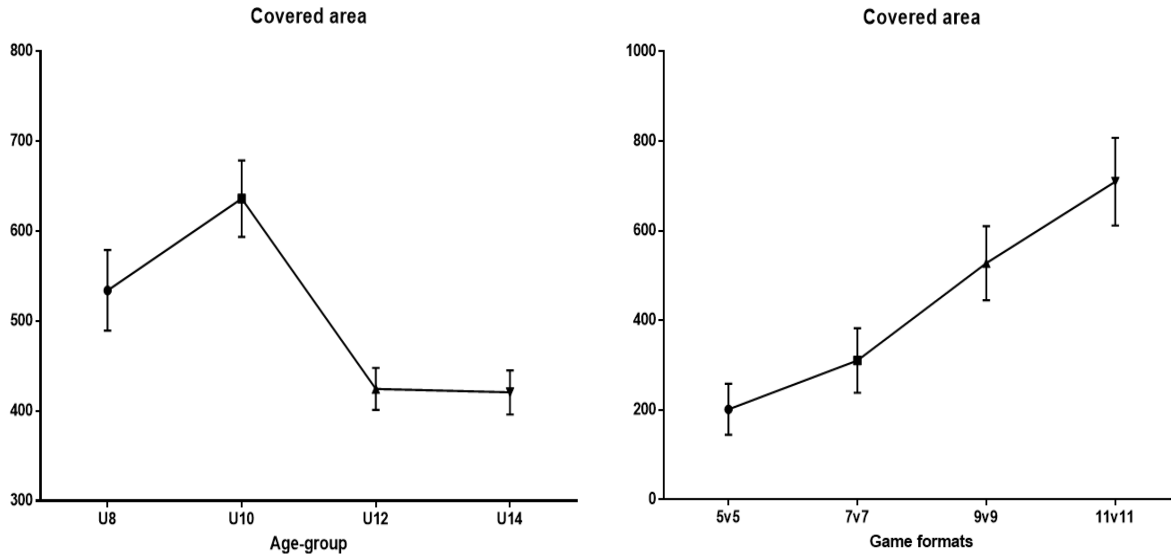

Figure 4. Mean values for covered area of the players on each age-group and game format. Error bars represent standard deviation.

Discussion

The aim of this study was to analyse the positioning and displacement of non-elite young soccer players (U8 to U14) during soccer matches performed in 5v5, 7v7, 9v9, and 11v11 game formats.

To assess the respective variables, linear and non-linear tools were used to analyse the spatial distribution variability and covered area by the players. These measures provide relevant information from the tactical point of view (Silva et al., 2015).

The results confirmed the hypothesis that the game formats and age-group induce differences in positioning and displacement of the players during soccer matches.

Spatial distribution variability

The Shannon entropy values showed that players´ spatial distribution variability was significantly different in the four game formats. In general, as the game format increased, players show more restricted action zones. Specifically, the action zones of the players were more restricted on 11v11 game format compared to the 5v5 and 7v7 formats, suggesting that the game formats with greater number of players induces behaviours of greater stability in which the players express movements of less variability and more predictable (Silva et al., 2015). Additionally, the addition of players to the context of the soccer match as well as the increase of the pitch dimensions promotes a higher level of collective organization, expressed in the optimization of the spatial distribution variability and behaviour of the players in the pitch (Aguiar et al., 2015).

In this context, it becomes clear that the smaller game formats induce greater amount of unintentional movements or actions that probably were not previously defined (i.e. non-systematic variability). Such characteristics of the movement may result from the systematic alternation between the defensive and attack mode that the players adopt during soccer match as well as the greater probability of the players being requested by their teammates through technical-tactical actions such as passing, game profile, tactical positioning, etc.

The Shannon entropy values also showed that the players´ spatial distribution variability is influenced by the age of the players. The spatial distribution of U10 age-group revealed significantly greater variability than the other groups, which suggests that players of different ages respond differently under the same game conditions. A possible explanation may be the inability of younger players to assimilate the tactical information that coaches give them, namely about the tactical positioning that they must adopt during the game. Another explanation may be the trend that players of U10 age-group manifest to chase the ball across all the pitch, which in turn induces a more anarchic style of play. Therefore, we can argue that, from the tactical point of view, the profile of the soccer match is more structured as the game format increased, in other words, the specificity of the tactical roles and the positioning of the players expresses a more balanced occupation of the pitch in the 9v9 and 11v11 game formats (Silva et al., 2014a). On the other hand, the 5v5 and 7v7 game formats seem to promote a faster style of play and in which players express more contacts with the ball, which in turn contributes to improve its technical and cognitive performance (Brito et al., 2018).

Relative positioning

The mean area covered by the players increase as the game format also increase. Since we are not aware of any comparable data in the literature, we can consider that it is expected that the average area covered by players is higher on soccer pitches of larger dimensions. A soccer match performed in pitch with larger dimension induces longitudinal and lateral movements of greater amplitude.

However, our results demonstrated that the U8 but mainly U10 age-group express longitudinal and lateral movements of amplitude significantly higher than the U12 and U14 age-groups. These data suggest that the players of 8-10 years-old are still unable to respond to the tactical demands imposed by the game. Moreover, it seems that the players of 8-10 years-old still do not have the capacity to respond to the tactical demands imposed by the soccer match. Consequently, the young players develop regular movements and of great amplitude but that nevertheless do not have correspondence in a greater intervention in the game, which induces a game less balanced from the tactical point of view.

Finally, analysis of ellipse forms also supported the assumption that the performance of players and teams is influenced by the format-age relationship. Specifically, we found that the relationship between longitudinal and lateral movements was more balanced in the following configurations: age-group U8 <> 5v5 game format; U10 <> 7v7; U12 <> 9v9; and U14 <> 11v11, respectively. The more rounded shapes in the mentioned configurations reflect the similarity of movement amplitudes in the longitudinal and lateral direction, suggesting that the profile of the game in the respective configurations was more structured and collective from a tactical point of view (Bartlett et al., 2012; Silva et al., 2014b; Stiles et al., 2009). The relationship between longitudinal and lateral movements was not as balanced in the other configurations whose ellipse forms reflected a less balanced player-space relationship as well as a poorer player-function relationship according to specific areas of the pitch (Duarte et al., 2012).

Future investigations may assess the effect of structural and functional constraints on the physiological and psychological performance of players. In addition, we suggest that it may be relevant to assess the physiological and psychological performance of the players under the effect of the variables mentioned.

Conclusions

We understand that the most accurate knowledge about the effect of the game format and age-group on the players´ tactical performance can help the coaches to use the most appropriate tools in the training process of young players and optimize their performance. Moreover, can also help governmental bodies to implement the most appropriate playing conditions in youth leagues soccer matches.

The main practical applications of this study are that the spatial distribution and displacements of the players is influenced significantly by the game format and age-group. Specifically, the 11v11 game format promotes greater stability in the variability and behaviour of spatial distribution of players in the pitch, suggesting that the specific positioning of players and their positional roles are more predictable. On the other hand, the small game formats, such as the 5v5, induce a greater amount of unintentional movements or actions, which can contribute to increase the tactical and technical participation of the players during the game.

In this study we also identified that at an early age (8-10 years), players tend to perform longitudinal and lateral movements of greater amplitude than the age groups U12 and U14, suggesting that at lower ages the players still have difficulty establishing a proficient relationship with the space.

Acknowledgments

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CHAPTER VI

General discussion

General discussion

This thesis results from an attempt to understand if the structural and functional game constraints of formal competition promote asymmetries in the physical, technical and tactical performance of young players. Since National Football Federations (e.g. *Federação Portuguesa de Futebol*) still seek to optimize the formal conditions of sports practice, it becomes relevant to examine the type of game formats used in youth championships and correlating them with the age of the players (considering the European context). And more specifically, it is important to assess the impact of the game constraints (e.g. pitch surface, game format and the age-group) in the performance of young players during competitive matches of youth leagues. Research efforts in this field can help coaches and government bodies to better understand the benefits of the process and the more relevant activities to support soccer players development in a competitive game environment (Cardinale, 2017).

Performance in soccer is a dynamically varying relationship resulting from the constraints imposed by the environment and the resources of the players (Araújo & Davids, 2011). Therefore, soccer players are active individuals engaged in ongoing dynamical transactions with the environment, i.e. the context in which the match takes place (Seifert, Araújo, Komar, & Davids, 2017). In this environment, it is accepted that players´ performance is governed by a complex interaction of variables, such as physiological, psychological, physical, biomechanical, and tactical variables, amongst others (Glazier, 2017). In its turn, these variables can be conditioned by the game constraints, i.e. the game conditions imposed by the organizational structure of the competition.

With the purpose to ensure a balanced competition organization structure, the Union of European Football Associations (UEFA) has been recommending that National Football Associations promote the organization of soccer matches adapted to the level of development and characteristics of the players (Arana et al., 2004). Consequently, the participation in youth soccer leagues has been part of the different sports programs organized by Federations and Football Associations for children and youngsters. The organizational structure of the competition, the objectives and the periodicity in which the competition takes place, as well as the appropriate age-group for the regular and more competitive beginning are aspects to be considered and investigated in the scope of sports science (Arena & Böhme, 2004). Specifically, how

European countries are managing the type of game formats used in youth championships and correlate them with the age of the players?

Conceptualization of the game formats used in European youth leagues

Knowledge about the utilization of different game formats throughout the diverse age-groups of youth soccer can provide evidence about how the European countries seek to adapt the organizational structure of the competition to the level of performance of young practitioners throughout their development process, particularly in the younger age stages. In this way, it will also be conceivable to understand whether the UEFA recommendations and the research evidence itself are being integrated in the European scenario.

According to Wein (1995), the organizational structure of each country should contemplate rules that promote the diversified and progressive use of game formats throughout the period related to the youth championships. Specifically, the same author suggests that it would be advantageous to progressively use the 3v3, 5v5, 7v7, 9v9 game formats before using the 11v11. The diversified and progressive use of 4 or 5 game formats before the 11v11 game condition can induce a more effective training and learning process. In addition, it provides that the transition to the next age-group is supported by a logic appropriate to the level of development and characteristics of the young players (Prado & Nava, 2007).

However, we found that 36% of European countries are using one to three game formats throughout the development process of young players. More specifically, six countries are using three game formats; five countries use two formats; and one country is using only the 11v11 format. According to this, it seems indicative that in some countries the organizational structure of soccer matches of youth championships is not appropriate to the needs and characteristics of young players (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012; Arana, 2011; Arana et al., 2004). This situation may be related to the fact that the leaders of their respective countries underestimate the importance of the game formal structure in the process of training players. Such situation could result from less sensitivity of the leaders of different countries, concerning the issues related to youth soccer; on the other hand, the current paradigm suggests that young soccer players are still forced to adapt to the formal structure of the soccer match (Prado & Nava, 2007), while it seems relevant that the formal structure of soccer match should be adapted to the characteristics of the players, namely their age and skills to respond to the requirements of the game context.

Fortunately, and according to the experts´ recommendations, most countries are already using four or five games formats during the competition associated with youth leagues. From the learning point of view, the progressive use of four or five game formats can contribute to the most effective development of the players (Wein, 1995; Williams & Hodges, 2005) since it allows them to practice and develop game actions in diverse contexts, which on the one hand, reflects an increase of the game experiences and, on the other hand, can contribute to when players have to meet the requirements of the game already have a vast amount of recorded memory that can help them to respond more quickly and adequately to the game requirements.

Correlating the game formats most used by the European countries with the age of the players it was possible to identify a certain pattern. We have found that 5v5, 7v7, 9v9, and 11v11 are the most commonly used game formats during youth league soccer matches. Specifically, we find that the 5v5 game format is mostly used in the U-8 age-group; the 7v7 reveals the highest use in U-10; the 9v9 appears as the most used in U-12; and the 11v11 in the U-14 age-group, respectively.

Although we already know under what conditions the youth league soccer matches are being performed, little is known about the effect that the actual game conditions impose on the performance of young players. For instance, the Portuguese youth soccer competitions are being carried out under the effect of specific structural and regulatory game constraints, such as the pitch surface, pitch dimension, the game format, and the age of the players. However, it is not known if these game constraints influence the performance of the players. Therefore, evaluate the performance of young players under the constraints imposed by the actual game conditions can make a decisive contribution to ensuring that young players perform soccer matches under game conditions adapted to their level of skill and age (Lapresa, Amatria, Egúen, Arana, & Garzón, 2008; Arana et al., 2004).

The effect of pitch surface on physical, technical and tactical performance of young soccer players

To assess whether the pitch surface has implications on the performance of young players during soccer matches, two studies were developed: i) a study to analyse the effect of pitch surface on running activity and technical performance of young players; ii) and another to investigate the effect of pitch surface on the variability of positioning and displacement of young players.

Although previous studies have already assessed the effect of natural turf and artificial turf on players´ performance, no study was found that analysed the physical, technical and tactical performance of the players in a soccer match context and in which the matches had been performed in the surfaces of natural turf, artificial turf and dirt field, the most used pitch surfaces in the soccer matches of the Portuguese youth leagues.

Therefore, this thesis seems an important step to show that pitch surface can induce asymmetries in the performance of young players and, in turn, on the performance and game profile of the respective teams during soccer matches.

Considering the values of the players´ running activity, the natural turf seems to induce greater requirement from the physical point of view compared to dirt field and mainly artificial turf. In all categories evaluated, the players performed less distance in natural turf compared to the other surfaces which suggests that natural turf imposes on players less ability to perform running activity. By the surface characteristics, the natural turf can induce fatigue more quickly, which in turn reduces players´ ability to respond to the demands of the soccer match. Thus, from physical viewpoint, the artificial turf emerges as the most balanced pitch surface to perform the soccer matches of youth leagues, since it reflects better ability to produce running activity for a longer period, inducing the increase of actions produced by the players during soccer match. We can support this argument by the fact the results have suggested that players have greater ability to perform high-intensity activities repeatedly (e.g. sprint activity) on artificial turf than on natural turf and dirt field.

Another curious fact that supports this argument was that younger players (age group 8-10 years) had lower running activity values than the older ones (age group 12-14 years), especially in natural turf. Therefore, since the physical capacity of the younger players is still underdeveloped at this stage (Papaiakovou et al., 2009) it is advisable to expose them to game contexts whose surface is less demanding from a physical point of view, such as artificial turf.

The results relating to the technical indicators also reinforce the presumption that artificial turf emerges as an excellent alternative to stimulate the proficiency of the technical actions performed by the players. It has been shown that players perform a greater amount of successful actions on artificial turf compared to the natural turf but mainly to dirt field. These data suggest that artificial turf provides a more effective interaction surface–ball and surface–player, reflected in the player´s superior ability to control the ball and consequent improvement of pass accuracy (Andersson et al., 2008; Burillo, Gallardo, Felipe, & Gallardo, 2014), which proves that technical performance is influenced by changes reflected in the playing conditions (Fajen, Riley, & Turvey, 2009). On the other hand, the dirt field has revealed the surface that expresses the most amount of unsuccessful actions, which suggests that the characteristic of this surface (harder and more irregular) tends: (i) to induce a greater obstacle for players to control the ball; (ii) to constraint the proficiency of the players´ actions; and (iii) to make the game profile of the team more direct and less structured from a tactical point of view.

Regarding the tactical perspective, our results suggests more uncertainty in the behaviour of the players in the dirt field compared to the other surfaces. In dirt field, the players tend to present greater variability in their spatial distribution, expressing movements of greater amplitude and flexibility. This variability suggests characteristics of being non-systematic, expressed in unintentional movements or behaviours not previously defined. Such movements and behaviours can result from the constant adaptations that players perform to overcome the constraints imposed by the surface characteristics as well as the ball trajectories, which on this surface express a greater irregularity and, consequently, induces a more random and individualistic game profile (Folgado, Lemmink, Frencken, & Sampaio, 2014).

On the other hand, the players presented less variability in their spatial distribution on artificial turf and natural turf, whose characteristics of these surfaces suggest inducing intentional and systematic behaviour or movements. Due to the characteristics of these surfaces as well as the movement and behaviour that players assume in them, we can argue that these surfaces promote the increase of ball circulation among the players reflecting, therefore, a more structured game profile from the tactical point of view. These data can be confirmed by analysing the covered area by the players (which represents the players´ movement in the pitch) and the ellipses forms (which suggest the main directions of the players´ movements and their distribution and relative positioning in the pitch). From its analysis, we can confirm that artificial turf reflects a more balanced configuration of different sections of the pitch. The elliptical configuration suggests a greater coordination between players, reflecting a more structured game profile from the tactical point of view and with greater amount of actions performed by the players (Bartlett, Button, Robins, Dutt-Mazumder, & Kennedy, 2012). On the other hand, the elliptic forms of the dirt field surface demonstrate that players´ movements in the pitch are mainly in the longitudinal direction, suggesting that this surface promotes a more vertical game style and dominated by long passes.

Thus, it is plausible to recognize that the players´ performance during a soccer match is influenced by a dynamically variable relationship that results from the constraints imposed by the environment and the resources of the players (Araújo & Davids, 2011), which ultimately can also influence the characteristics of the respective soccer match (Andersson et al., 2008; Stiles, James, Dixon, & Guisasola, 2009). Since players have greater difficulty in responding to the demands and constraints of the game at the earliest ages, the coaches and the government bodies should consider that the surface used to perform soccer matches should not be one more factor to limiting the players performance.

In short, the data from this thesis suggest that artificial turf is the surface that induces fewer constraints on the players´ physical, technical and tactical performance. Specifically, the artificial turf is the surface that requires less adaptability, and, which in turn, induces less variability and flexibility of behaviours and movements. On the other hand, the dirt field is the surface that requires greater capacity of adaptations to the players, promoting, therefore, behaviours and movements of greater variability and flexibility.

The effect of game formats on physical and tactical performance of young soccer players

To assess whether the game formats has implications on the performance of young players during soccer matches, two studies were developed: i) a study to inquire the effect of game format and age-group on running activity performance of young players; ii) and another to investigate the influence of the game format on the variability of positioning and displacement of young players.

Investigate the role of structural and functional constraints in youth soccer competitions is justified because there is still little scientific dissemination about this subject (Brito, Roriz, Duarte, & Garganta, 2018), especially regarding the use of different game formats during soccer matches of the youth leagues. For instance, what are the implications on players performance when using the 5v5, 7v7, 9v9 or 11v11 game formats to perform the official youth leagues soccer matches along the development stages of players? And, more specifically, what is the impact of using the large game formats (such as the 11v11) at lower ages?

The present thesis demonstrate that game formats and age-group promote asymmetries in the physical and tactical performance of young players as well as on the game profile of the respective teams during soccer matches.

Specifically, and from a physical perspective, it was demonstrated that the 11v11 game format imposes a greater running activity to the players than the other formats in all categories, especially in relation to the 5v5. The fact of imposing greater running activity associated with the smaller capacity of the young players to produce the respective activity, mainly the activity in higher intensity thresholds, suggests that 11v11 format, which is used in soccer pitches with larger dimensions, represents an additional constraint on player performance, especially at lower ages.

Concomitantly, the running activity of the players during soccer matches was similar between the intermediate game formats (5v7 and 7v9, respectively), suggesting that the game transition from 5v5 to 7v7 as well as from 7v7 to 9v9 does not reflect a marked impact on the running activity requirement imposed to the players, confirming that the progressive use of various game formats until reaching the 11v11 format reduces the impact on the players-performance-environment relationship (Wein, 1995). In addition, and since the 5v5 and 7v7 formats induce less demanding running activity on the players, suggests that they may be more available to increase concentration and decision-making ability in formats with fewer players, improving therefore the ability to respond to the other game requirements. This scenario confirms that soccer match conditions can be a decisive factor in the player development process (Reilly, Bangsbo, & Franks, 2000), in which the game formats used in the youth league soccer matches can make a relevant contribution to the process.

Our findings also demonstrated that the younger age-groups cover a shorter distance in all running activity categories than the older-groups, as previously shown by (Buchheit et al., 2010). Even so, the observed differences were more pronounced in high-intensity running activity thresholds, suggesting that players from 8 to 12 years have not yet developed the ability to be systematically exposed to produce activity within the mentioned thresholds. Thus, it seems premature to expose players from 8-12 years to soccer matches in the 11v11 format, whose soccer pitch has large dimensions and for this reason submit the players to longer-distance running.

Regarding the tactical perspective, our results demonstrated that the action zones of the players were more restricted on 11v11 and 9v9 game formats compared to the 5v5 and 7v7 formats. This pattern suggests that, on the one hand, the players explore more variable areas of the pitch in the 5v5 and 7v7 game formats, reflecting greater uncertainty in their behaviours (Silva et al., 2015) and, on the other hand, the addition of players to the soccer match context promotes a higher level of collective organization, expressed in the optimization of the distribution and behaviour of the players in the pitch (Aguiar et al., 2015). In this perspective, it is pertinent to consider that the use of game formats with fewer players, such as the 5v5 and 7v7 formats, can contribute: (i) for the players to retain their physical and physiological capacity over a longer period during the soccer match, which in turn will reflect movements of greater amplitude; ii) to increase the probability of players being requested by their teammates through passes, inducing the increase of their intervention and/or participation during the game; and iii) makes the players´ tactical positioning more versatile, reflected in the systematic alternation between the defense and attack mode that players are forced to adopt, which in turn induces the increase of tactical experiences during the game.

Another interesting fact was that U10 age-group show higher entropy values than all other groups. The highest values of entropy evidenced by the U10 age-group may be associated with the fact that at this stage of the player development process, the 10-year-old practitioner still does not have a well-established tactical construct, which makes him more curious about what is going on around him. This specific curiosity, associated with the lack of tactical knowledge still evident at this age, promotes in each player the temptation to chase the ball across all the pitch, without the ability to discern the tactical positioning that was previously assigned to them by the coach.

The arguments presented above can also be supported by data relating to the covered area by the players. Specifically, the results of this thesis demonstrate that the age-groups U8 and mainly U10 cover a significantly mean larger area than the U12 and U14 groups, which confirms that the players of 8-10 years-old are still unable to respond to the tactical demands imposed by the game. Concomitantly, the inability demonstrated by younger players to respond to tactical demands, promotes an anarchic style of play in which the players tend to chase the ball across all the pitch.

This pattern was most pronounced in the game formats with highest number of players, such as 9v9 and 11v11, which demonstrates that younger players express indicators that suggest a poor player-space relationship. Therefore, it is demonstrated that the dimensions of the soccer pitch (Jones & Drust, 2007) and the number of players (Clemente, Couceiro, Martins, Dias, & Mendes, 2012) constrains the positioning and displacement of players during soccer matches, being that in lower ages the effect of this constraint achieves higher proportions.

In this context, it becomes determinant to adapt the structure of the soccer match to the characteristics of the players (Lapresa et al., 2009; Capranica et al., 2001). For this purpose, it is relevant to determine which is the most appropriate game format for each age-group. Analysis of ellipse shapes provides more accurate information about the structure of the soccer match most appropriate to each age-group. Through Figure 4 of the fifth study, we can support the assumption that the player-space-colleagues´ relationship is influenced by the game format and the age-group. Analyzing the ellipse shapes, we can confirm that the smallest eccentricity and/or the greatest overlapping of the elliptic forms in the following configurations (U8 <> 5v5; U10 <> 7v7; U12 <> 9v9; and U14 <> 11v11) express: i) a more balanced configuration of the different sections of the pitch; ii) a greater coordination between the players; iii) longitudinal and lateral movements with a similar amplitude; iv) a more structured and collective game profile; and v) a concept of game more elaborated tactically, where ball circulation predominates (Bartlett et al., 2012; Silva et al., 2014; Stiles et al., 2009).

In this perspective, we can argue that soccer matches performed in a game format appropriate to the age of the players can contribute to improve the player-space-colleagues´ relationship, which in turn also improves the tactical balance of the teams and induces a more positive style of play. As suggested by Silva et al. (2014), the smaller eccentricity of the ellipses reflects a more balanced occupation of the different sections of the pitch which improves the acquisition of tactical principles and favors successful performance in soccer matches (Teodorescu, 1977).

In summary, the results confirm that the use of the most appropriate game format in relation to the age of the players contributes decisively to improving the development process of young players as it encourages the acquisition and assimilation of the tactical parameters of young players. On the other hand, it also promotes a more positive style of play in which player participation is more proficient.

CHAPTER VII

Conclusions

Conclusions

According to the results reported in the different studies developed for this thesis, it is possible to present the following conclusions:

- The young players´ running activity proved to be consistently lower on the natural turf. On the other hand, it was evident that the players showed a greater predisposition to perform running activity on the artificial turf;
- The dirt field is cause of constraint in the execution of technical actions, significantly increasing the number of unsuccessful actions. On the other hand, the artificial turf promotes the increase of the proficiency in the execution of the respective actions;
- From the tactical point of view, the artificial turf induces a more structured style of play, whereas, in contrast, the dirt field promotes a poorer style of play, in which players consistently exhibit more unstable and random movements;
- The 11v11 game format induces a significant increase in the running activity, as well as a greater stability in the positioning and displacement variability of the players compared to the 5v5 and 7v7 formats;
- The small game formats, such as 5v5 and 7v7, promote the increase of random movements and unintentional actions, reflecting also greater variability in the positioning of the players during soccer matches;
- Older players (U14) demonstrate a consistently superior ability to cover, in all categories, greater distances of running activity compared to their younger counterparts;
- The players of the U8 and U10 age-groups show a clear predisposition to perform longitudinal and lateral movements of greater amplitude than the U12 and U14 age-groups.

As a final consideration, the results of this thesis confirm that the structural and functional model of youth competition is a cause of constraint on the performance of young soccer players. Thus, we can also argue that a game context that does not allow to develop the proficiency of the players performance must be reformulated with purpose of increasing the density and proficiency of the actions and behaviours performed during soccer matches.

We recognise that the most accurate knowledge about adaptations imposed by each pitch surface, game format and age-group may contribute, on one hand, for the coaches to use the most appropriate tools in the young players training process and optimise their performance; on the other hand, it can help the coaches and national governing bodies to implement adequate practice conditions in which the requirements of the game are appropriate in relation to the age and characteristics of the young soccer players.

Suggestions for future studies

The present thesis allowed to formulate a set of questions that can contribute to increase the knowledge about the problem of the study.

Although the results achieved by the present thesis and its conclusions have evidenced the influence of the pitch surface, age-group, and game format on the performance of young players, it would be pertinent to analyse the physiological and psychological impact that these variables promote.

It is also important to analyse whether in the context of training some of the variables mentioned above, namely the pitch surface and the game format can contribute to the improvement of the players´ performance indicators.

In addition, it would also be of interest to broaden and diversify the sample to determine whether there are ages or formats in which the acquisition of performance proficiency is facilitated.

Lastly, we understand that it would be relevant to use the same design of this thesis to manipulate other forms of constraints, namely the pitch dimension, the size of the goals and the tactical disposition of the teams.

Proposals to configure the game context in youth championships

The current thesis allows to list a set of suggestions that can contribute to expose the participants to soccer matches in the most appropriate environment.

- We suggest the artificial turf for youth championships soccer matches, as this surface promotes a structured tactical style of play, as well as greater proficiency in the execution of technical actions;
- The 5v5, 7v7, 9v9 and 11v11 game formats are sufficiently consistent and suitable to be used in the U8, U10, U12 and U14 age-groups respectively;
- Since it is still little used, the use of the 9v9 game format in youth championships should be encouraged. Firstly, because it will increase players´ practice experiences during their development process, and secondly because it will reflect a progressive and balanced transition until the 11v11 format;
- Lastly, we suggest that the pitch dimensions increase proportionally in relation to the number of players, standardising therefore the relative space per player. For this, we suggest the following configuration:

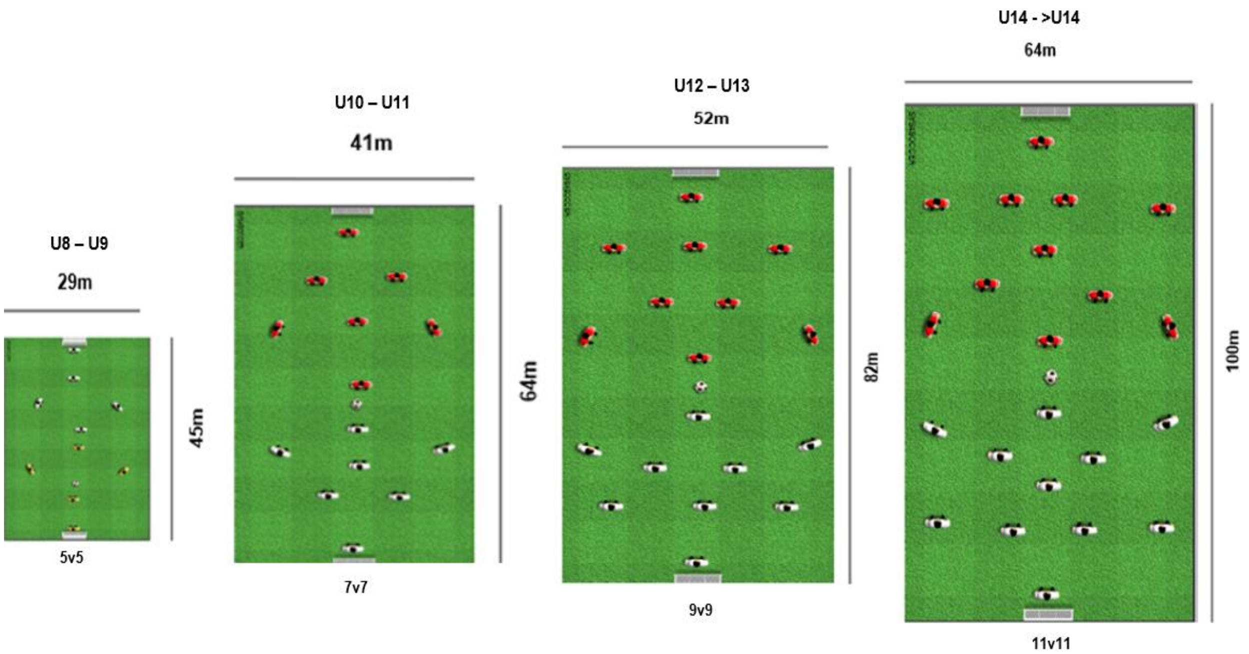

Figure 1. Proposal to perform youth soccer matches.
Note: Age-groups (U8, U10, U12, and U14). Game formats (5v5; 7v7; 9v9; and 11v11).

CHAPTER VIII

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