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

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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: $\eta^2 = .062$, $p \le .05$); and (VHIR: $\eta^2 = .05$, $p \le .05$), 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.

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Assessment; Time–motion; performance analysis; technical demands; team sport

1. 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, Gómez, Gonçalves, & Sampaio, 2016). Despite performance could depend on a myriad of factors (Stølen, Chamari, Castagna, & Wisløff, 2005), according to Impellizzeri and Marcora (2009), the physical, technical and tactical indicators are probably the most relevant in the analysis

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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, Maçãs, & 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 Román, & 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.

2. Methods

2.1. 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.

2.2. 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.

2.3. 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 (.2 s) 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.

2.4. 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.

2.5. 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.

3. Results

3.1. 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. $\eta^2 = .09$, $p = .007$). 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. $\eta^2 = .062$ and $\eta^2 = .05$ 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.

3.2. 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. $\eta^2 = .052$, $p = .051$). Conversely, the unsuccessful passing was greatest on dirt field than artificial and natural turf (e.g. $\eta^2 = .155$, $p < .001$). Finally, the interceptions were greatest on dirt field than natural turf (e.g. $\eta^2 = .1087$, $p < .001$). Dirt field was associated with large effect size ($\eta^2 \ge .14$) 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

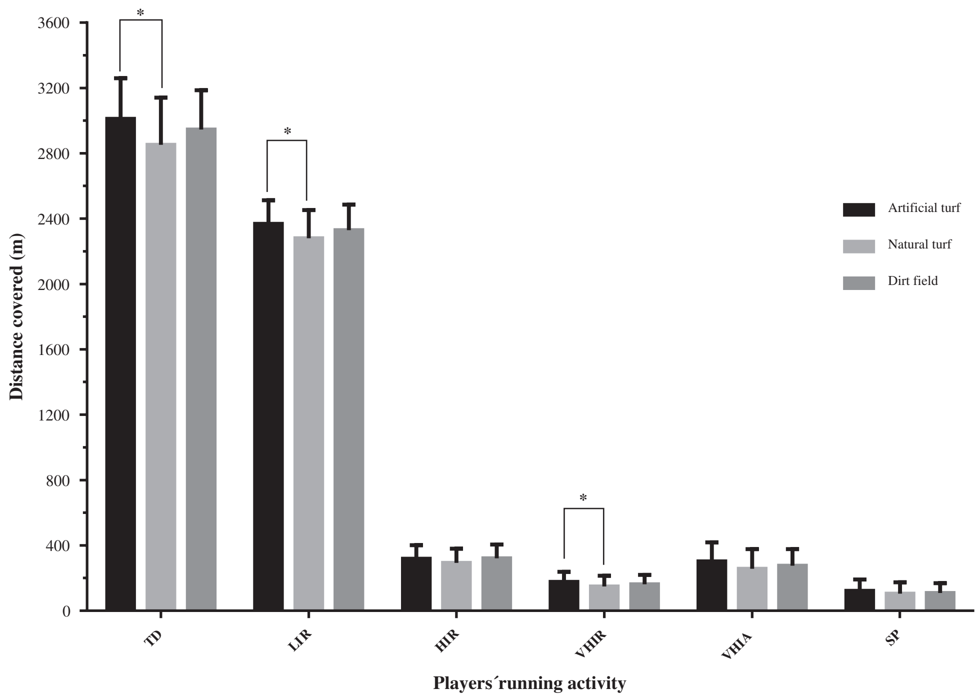

Figure 1. Players' running activity on each pitch surface condition (mean ± SD).
Notes: Running activity categories: total distance covered (TD), low-intensity running (LIR; running speed < 13.0 km.h^{-1}), high-intensity running (HIR; running speed from 13.1 to 16 km.h^{-1}), very high-intensity running (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 difference 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.

4. 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 to (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	$p = .129$	

Notes: 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 difference between conditions; *($p < .05$); and **($p < .001$). Playing positions categories: CD = Central defenders; CF = Centre forwards; CM = Central midfielders; WM = Wide midfielders; FB = Fullbacks.

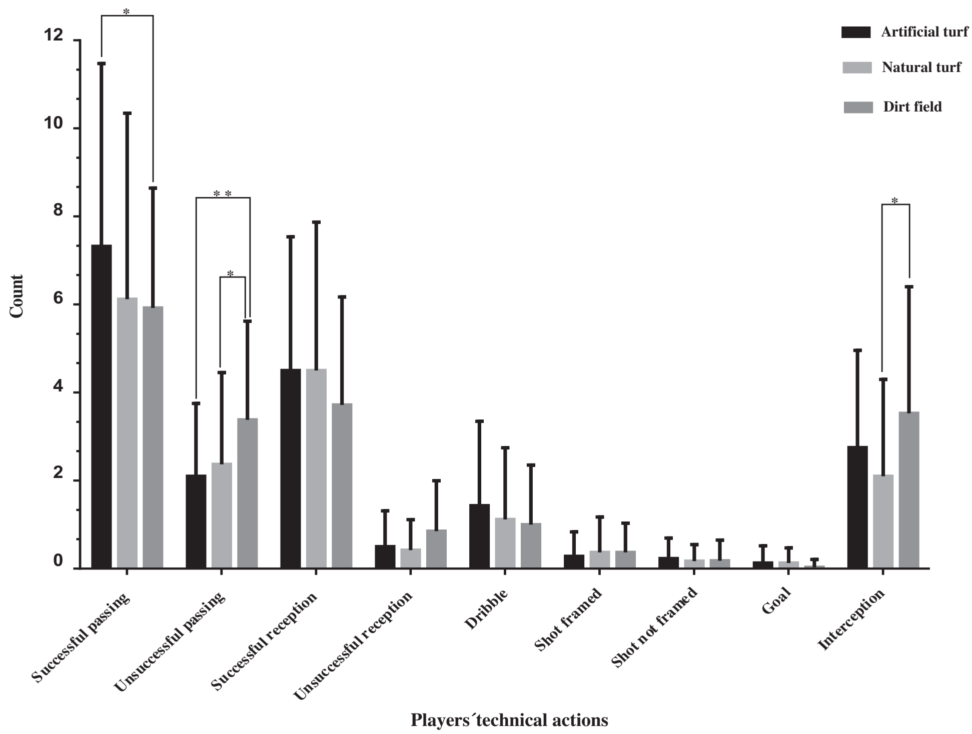

Figure 2. Players' technical actions on each pitch surface condition (mean ± SD).
Notes: Significant difference between conditions; *($p < .05$) and **($p < .001$). Pitch surfaces: AT = Artificial turf; NT = Natural turf; DF = Dirt field.

(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

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	.50 ± .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	.50 ± .81	.33 ± .89	1.17 ± 1.17	.39 ± .50	.83 ± 1.03	.17 ± .39	$p = .057$	
	NT	.42 ± .70	.50 ± .80	1.17 ± 1.17	.33 ± .49	.25 ± .62	.25 ± .45	$p = .061$	
	DF	.85 ± 1.15	.25 ± .62	1.17 ± 2.04	.94 ± 1.06	1.50 ± 1.31	.50 ± .52	$p = .059$	
Dribble	AT	1.43 ± 1.92	.08 ± .29	.50 ± .55	2.17 ± 2.18	3.00 ± 2.17	.58 ± .79	$p < 0{,}001$	CD < CM*; CD < WM**; CF < WM*; WM > FB*
	NT	1.12 ± 1.63	.33 ± .49	.50 ± .84	1.17 ± 1.47	2.67 ± 2.43	.58 ± .79	$p = .002$	CD < WM*; CF < WM*; WM > FB*
	DF	1.00 ± 1.35	.25 ± .62	1.00 ± 1.11	1.06 ± .99	2.17 ± 2.08	.50 ± .80	$p = .004$	CD < WM*; WM > FB*
Shot framed	AT	.28 ± .56	.00 ± .00	.50 ± .55	.61 ± .70	.25 ± .62	.00 ± .00	$p = .006$	CD < CM*; CM > FB*
	NT	.37 ± .80	.00 ± .00	.33 ± .52	.78 ± 1.22	.50 ± .67	.00 ± .00	$p = .033$	
	DF	.37 ± .66	.25 ± .45	1.17 ± 1.17	.61 ± .70	.00 ± .00	.08 ± .29	$p = .001$	CD < CF*; CF > WM*; CF > FB*
Shot not framed	AT	.23 ± .47	.08 ± .29	.33 ± .52	.50 ± .62	.08 ± .29	.08 ± .29	$p = .035$	
	NT	.17 ± .38	.00 ± .00	.17 ± .41	.33 ± .49	.17 ± .39	.08 ± .29	$p = .163$	
	DF	.18 ± .47	.25 ± .45	.33 ± .82	.28 ± .58	.08 ± .29	.00 ± .00	$p = .421$	
Goal	AT	.13 ± .39	.00 ± .00	.33 ± .52	.28 ± .58	.08 ± .29	.00 ± .00	$p = .128$	
	NT	.13 ± .34	.00 ± .00	.17 ± .41	.22 ± .43	.25 ± .45	.00 ± .00	$p = .177$	
	DF	.03 ± .18	.00 ± .00	.17 ± .41	.06 ± .24	.00 ± .00	.00 ± .00	$p = .320$	

(*Continued*)

Table 2. (*Continued*).

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)
Interception	AT	2.75 ± 2.21	4.58 ± 2.61	.33 ± .52	3.08 ± 1.94	1.25 ± .97	3.11 ± 1.68	$p < 0{,}001$	CD > CF**; CD > WM**; CF < CM*; CF < FB*
	NT	2.10 ± 2.20	3.67 ± 1.78	.50 ± .55	1.61 ± 1.88	1.17 ± .94	3.00 ± 3.16	$p = .004$	CD > CF*; CD > WM*
	DF	3.53 ± 2.87	6.25 ± 3.31	.67 ± .82	3.44 ± 2.38	1.58 ± 1.17	4.33 ± 2.35	$p < 0{,}001$	CD > CF**; CD > CM*; CD > WM**; CF < FB*

Notes: Significant difference between conditions; *($p < .05$); and **($p < .001$). Playing positions categories: CD = Central defenders; CF = Centre forwards; CM = Central midfielders; WM = Wide midfielders; FB = Fullback.

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 non-elite 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.

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 similar to 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 have 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.

5. 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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References

Andersson, H., Ekblom, B., & Krustrup, P. (2008). Elite football on artificial turf versus natural grass: Movement patterns, technical standards, and player impressions. *Journal of Sports Sciences, 26*(2), 113–122.

Bathke, A. C., Schabenberger, O., Tobias, R. D., & Madden, L. V. (2009). Greenhouse–Geisser adjustment and the ANOVA-type statistic: Cousins or twins? *The American Statistician, 63*(3), 239–246. doi:10.1198/tast.2009.08187

Binnie, M. J., Dawson, B., Arnot, M. A., Pinnington, H., Landers, G., & Peeling, P. (2014). Effect of sand versus grass training surfaces during an 8-week pre-season conditioning programme in team sport athletes. *Journal of Sports Sciences, 32*(11), 1001–1012.

Bradley, P., Carling, C., Archer, D., Roberts, J., Dodds, A., Di Mascio, M., & Krustrup, P. (2011). The effect of playing formation on high-intensity running and technical profiles in English FA premier league soccer matches. *Journal of Sports Sciences, 29*(8), 821–830.

Bradley, P., Di Mascio, M., Peart, D., Olsen, P., & Sheldon, B. (2010). High-intensity activity profiles of elite soccer players at different performance leveles. *Journal of Strength and Conditioning Research, 24*(9), 2343–2351.

Bradley, P., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA premier league soccer matches. *Journal of Sports Sciences, 27*(2), 159–168.

Brito, J., Krustrup, P., & Rebelo, A. (2012). The influence of the playing surface on the exercise intensity of small-sided recreational soccer games. *Human Movement Science, 31*(4), 946–956.

Buchheit, M., Mendez-Villanueva, A., Simpson, B., & Bourdon, P. (2010). Match running performance and fitness in youth soccer. *International Journal of Sports Medicine, 31*(11), 818–825.

Burillo, P., Gallardo, L., Felipe, J. L., & Gallardo, A. M. (2014). Artificial turf surfaces: Perception of safety, sporting feature, satisfaction and preference of football users. *European Journal of Sport Science, 14*(sup1), S437–S447.

Butterworth, A., O'Donoghue, P., & Cropley, B. (2013). Performance profiling in sports coaching: A review. *International Journal of Performance Analysis in Sport, 13*(3), 2–2.

Casamichana, D., & Castellano, J. (2010). Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *Journal of Sports Sciences, 28*(14), 1615–1623.

Casamichana, D., Castellano, J., Calleja-Gonzalez, J., San Román, J., & Castagna, C. (2013). Relationship between indicators of training load in soccer players. *The Journal of Strength & Conditioning Research, 27*(2), 369–374.

Castagna, C., D'Ottavio, S., & Abt, G. (2003). Activity profile of young soccer players during actual match play. *Journal of Strength and Conditioning Research, 17*(4), 775–780.

Castellano, J., Puente, A., Echeazarra, I., Usabiaga, O., & Casamichana, D. (2016). Number of players and relative pitch area per player: Comparing their influence on heart rate and physical demands in under-12 and under-13 football players. *Plos One, 11*(1), e0127505.

Clemente, F., Couceiro, M., Martins, F., & Mendes, R. (2012). Team's performance on FIFA U17 World Cup 2011: Study based on notational analysis. *Journal of Physical Education and Sport, 12*(1), 13.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: A systematic review. *Sports Medicine, 43*(10), 1025–1042.

Dellal, A., Moalla, W., Chamari, K., & Wong, D. P. (2010). Physical and technical activity of soccer players in the French first league with special reference to their playing position. *International SportMed Journal, 11*(2), 278–290.

Dellal, A., Owen, A., Wong, D. P., Krustrup, P., van Exsel, M., & Mallo, J. (2012). Technical and physical demands of small vs. large sided games in relation to playing position in elite soccer. *Human Movement Science, 31*(4), 957–969.

Fajen, B., Riley, M., & Turvey, M. (2009). Information, affordances, and the control of action in sport. *International Journal of Sport Psychology, 40*(1), 79.

FIFA. (2007). *Technical study with prozone*. Retrieved 8 January, 2012, from http://www.fifa.com/mm/document/footballdevelopment/pitch&equipment/50/16/14/turf_roots_1_11166.pdf

Folgado, H., Duarte, R., Laranjo, L., Sampaio, J., & Fernandes, O. (2007). *Heart rate and technical responses to variation in pitch dimension and surface in "three-a-side"youth soccer drills*. Retrieved 20 January, 2013, from http://hdl.handle.net/10174/2086

Gabbett, T. J., & Mulvey, M. J. (2008). Time-motion analysis of small-sided training games and competition in elite women soccer players. *Journal of Strength and Conditioning Research, 22*(2), 543–552. doi:10.1519/JSC.0b013e3181635597

Gonçalves, B. V., Figueira, B. E., Maçãs, V., & Sampaio, J. (2014). Effect of player position on movement behaviour, physical and physiological performances during an 11-a-side football game. *Journal of Sports Sciences, 32*(2), 191–199.

Goto, H., Morris, J. G., & Nevill, M. E. (2015). Motion analysis of U11 to U16 elite English premier league academy players. *Journal of Sports Sciences, 33*(12), 1248–1258.

Impellizzeri, F. M., & Marcora, S. M. (2009). Test validation in sport physiology: Lessons learned from clinimetrics. *International Journal of Sports Physiology and Performance, 4*(2), 269–277.

James, N. (2006). Notational analysis in soccer: Past, present and future. *International Journal of Performance Analysis in Sport, 6*(2), 67–81.

Johnston, R. J., Watsford, M. L., Pine, M. J., Spurrs, R. W., & Sporri, D. (2013). Assessment of 5 Hz and 10 Hz GPS units for measuring athlete movement demands. *International Journal of Performance Analysis in Sport, 13*(1), 262–274.

Jones, S., & Drust, B. (2007). Physiological and technical demands of 4 v 4 and 8 v 8 games in elite youth soccer players. *Kinesiology, 39*(2), 150–156.

Liu, H., Gómez, M. A., Gonçalves, B., & Sampaio, J. (2016). Technical performance and match-to-match variation in elite football teams. *Journal of Sports Sciences, 34*(6), 509–518.

Mackenzie, R., & Cushion, C. (2013). Performance analysis in football: A critical review and implications for future research. *Journal of Sports Sciences, 31*(6), 639–676.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Science, 21*(7), 519–528.

Owen, A. L., Wong, D. P., McKenna, M., & Dellal, A. (2011). Heart rate responses and technical comparison between small- vs. large-sided games in elite professional soccer. *Journal of Strength and Conditioning Research, 25*(8), 2104–2110. doi:10.1519/JSC.0b013e3181f0a8a3

Praça, G., Soares, V., Matias, C., Costa, I., & Greco, P. (2015). Relationship between tactical and technical performance in youth soccer players. *Revista Brasileira de Cineantropometria & Desempenho Humano, 17*(2), 136–144.

Rebelo, A., Brito, J., Maia, J., Coelho-e-Silva, M., Figueiredo, A., Bangsbo, J., & Seabra, A. (2013). Anthropometric characteristics, physical fitness and technical performance of under-19 soccer players by competitive level and field position. *International Journal of Sports Medicine, 34*(4), 312–317. doi:10.1055/s-0032-1323729

Rebelo, A., Brito, J., Seabra, A., Oliveira, J., & Krustrup, P. (2014). Physical match performance of youth football players in relation to physical capacity. *European Journal of Sport Science, 14*(sup1), S148–S156.

Santos, R., Dias, C., Garganta, J., & Costa, I. (2013). Does playing surface influence the tactical performance of soccer players? *Revista da Educação Física/UEM, 24*(2), 247–252.

Schlegel, M. (2009). Does the game change?: Natural grass versus artificial turf sporting surfaces. *Chemistry in Australia, 76*(6), 14.

Silva, P., Esteves, P., Correia, V., Davids, K., Araújo, D., & Garganta, J. (2015). Effects of manipulations of player numbers vs. field dimensions on inter-individual coordination during small-sided games in youth football. *International Journal of Performance Analysis in Sport, 15*(2), 641–659.

Sinnott, R. W. (1984). Sky and telescope. *Virtues of the Haversine, 68*(2), 159.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of Soccer. *Sports Medicine, 35*(6), 501–536.

Varley, M. C., & Aughey, R. J. (2013). Acceleration profiles in elite Australian soccer. *Intenational Journal of Sports Medicine, 34*(1), 34–39. doi:10.1055/s-0032-1316315