Chapter 2
Physiological Demands of the Soccer and Time–Motion Profile

Abstract The training process must follow the specificity of the sport. Thus, identify the physiological demands of the game, the time–motion profile of the players, the physical specificities of the players, and the technical actions and tactical behaviors that are most common in soccer which is important. By knowing these characteristics it will be easier to develop the training tasks and correctly prescribe these tasks in the weekly periodization.

Keywords Physiological demands · Time–motion analysis · Match analysis · Soccer · Football · Sports performance

2.1 Introduction

Soccer is an invasive team sport with duration of 90 min with intermittent regimen of effort (Reilly and Williams 2003). This intermittent regimen depends from many contextual variables that determine the pace of the players and the dynamics of the game (Carling et al. 2005). The type of actions and skills and the profile of motion lead to different interventions that coach may prescribe and for that reason the overall results should be carefully analyzed by different variables such as tactical role, tactical lineup of the team, or the style of play (Carling 2013).

Usually, the motion analysis and more particularly the intensity of running and distance covered provide relevant information about the activity profile that occurs in match (Buchheit et al. 2014). The work-rate measure can be broken down into discrete actions of a player for a whole game (Rampinini et al. 2007). The activity or activities of players can be classified based on type, intensity (or quality), duration (or distance), and frequency (Reilly and Williams 2003). Nowadays, some technological devices provide the opportunity to measure such indicators (Clemente et al. 2014a): (i) multi-camera tracking systems; (ii) global positioning system (GPS); and (iii) radio-frequency identification (RFID).

Only activity does not characterize the demands of the game. For that reason, some physiological responses (heart rate, rated perceived exertion, or blood lactate

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concentrations) have been also monitored during games (Datson et al. 2014; Mohr et al. 2005). By using such information it will be possible to better understand the physical and physiological requirements of the game, thus improving the capacity to develop the specificity of the training (Little 2009; Turner and Stewart 2014).

This chapter aims to examine some aspects of the exercise intensities in soccer. Acute physiological responses, time–motion profile of players, and match analysis will be the focus of this chapter. In the end of this chapter, the practical implications for training context will be discussed.

2.2 Time–Motion Analysis

Elite soccer players commonly cover values of 10–12 km during a game (Carling et al. 2008; Di Salvo et al. 2007; Stroyer et al. 2004). The majority of studies report that central midfielders and wide defenders run the longest distances during a match and central defenders and strikers the shortest distances (excluding goalkeepers) (Clemente et al. 2013; Di Salvo et al. 2007; Mohr et al. 2003). Actually, the linking role of central midfielders may determine the greater distances covered (Mendez-Villanueva et al. 2012; Reilly 2007a, b). Defenders perform the largest amount of jogging, skipping, and shuffling movements and spend a significantly smaller amount of time sprinting and running than other players (Bloomfield et al. 2007). Another evidence is that professional and elite players run longer distances than nonprofessional or moderate players (Ekblom 1986). In this particular case, top class players may perform more 28 % of high-intensity running and 58 % of sprint than moderate players (Mohr et al. 2003). The effect of fatigue induce a decrease of 5–10 % in the total distance from the first to the second half of the match in the majority of the cases reported (Carling et al. 2005; Mohr et al. 2003; Rienzi et al. 2000).

The intermittent regimen of soccer can be associated with the evidence that a sprint bout occurs every 90 s, each lasting an average of 2–4 s (Bangsbo et al. 1991; Rienzi et al. 2000; Stølen et al. 2005). Generally, the average distance covered at high intensity is 10 % (Carling et al. 2008). Some results suggested that wide midfielders, attackers, and wide defenders covered higher total sprint distance than central defenders and central midfielders (Bradley et al. 2009; Di Salvo et al. 2007, 2010). Wide midfielders performs more sprints (>25.2 km h^{-1}), followed by attackers and wide defenders (Di Salvo et al. 2007, 2010). Central defenders perform fewer explosive and leading sprints than all other field positions (Di Salvo et al. 2010). A more recent study that analyzed the distance covered at low, moderate, and high-acceleration and deceleration revealed that on average 18 % of total distance covered is done so whilst accelerating or decelerating at a rate greater than 1 ms^{-2} (Akenhead et al. 2013). The authors also revealed that 7.5, 4.3, and 3.3 % of total distance is covered at 1–2 ms^{-2}, 2–3 ms^{-2}, and >3 ms^{-2}, respectively. It was concluded in this study that time-dependent reductions in distances covered suggest that acceleration and deceleration capability are acutely compromised during match play (Akenhead et al. 2013).

In youth levels, some studies that analyzed the sprinting performance during match play indicated that younger players competed at higher relative running intensities than their older counterparts (Buchheit et al. 2010; Mendez-Villanueva et al. 2012). By the other hand, it was possible to verify that few differences in match work rate were found between groups in a comparative study from U12 to U16 (Harley et al. 2010). Also in youth players some findings suggested that irrespective of the age group, players covered less distance in the second half than in the first half (Mendez-Villanueva et al. 2012). As similar to elite, in youth soccer generally midfielder covered the greatest distance at low relative speeds while striker displayed the lowest distance at intensities below maximal aerobic speed (Mendez-Villanueva et al. 2012).

During a match each player performs 1000–1400 short activities changing every 4–6 s (Bangsbo et al. 1991; Reilly and Thomas 1976; Stølen et al. 2005). The ratio of low intensity to high-intensity efforts is about 5:2 in terms of distance covered (Reilly and Williams 2003). Nevertheless, based on time the ratio may achieve 1:8 in 90 % of cases with an intermittent effort profile of 2.2 s/18 s (Vigne et al. 2010). On average each outfield player has a short static rest pause of only 3 s every 2 min (Reilly 2007a, b). Sprints, high-intensity running, tackles, headings, involvements with ball, or passes are the common activities that intermittently occurred during a match. Nevertheless, in professional soccer only 1.2–2.4 % of the total distance covered by players is in possession of the ball (Carling 2010; Rampinini et al. 2009). Such activity increases the physiological stress in comparison with running without ball at the same speed (Hoff et al. 2002). In a study that analyzed the specific patterns of activity in moments with ball it was found that actions are most commonly undertaken at high running speed (>10 km h^{-1}) (Carling 2010).

2.3 Acute Physiological Responses

Both intermittent activity profile of the game and the game duration contribute for the physiological stress experienced by the players. The game duration determine the mainly dependence from the aerobic metabolism (Stølen et al. 2005). The average work intensity measured by maximal heart rate (HRmax) reveals a profile of activity close to anaerobic threshold (80–90 % HRmax or 75 %VO_{2max}) (Hoff et al. 2002; Mohr et al. 2005). Average blood lactate concentration of 3–6 mmol l^{-1} has been verified during matches, with specific individual cases above 12 mmol l^{-1} (Bangsbo 1994; Mohr et al. 2005). The peak values may occur in man-to-man duels (Gerisch et al. 1988). These great values suggest that the anaerobic energy system can be highly taxed during intense periods of the game (Mohr et al. 2005). Nevertheless, this intensity cannot be sustained continuously under these extreme conditions, which reflect the intermittent consequences of anaerobic metabolism during soccer match (Reilly 2007a, b).

The measuring of oxygen uptake in a match was also investigated in periods of 3 min in two players (Ogushi et al. 1993). In this study it was found values of 35–38 mL/kg/min in first half and 29–30 mL/kg/min in second half which corresponding to 56–61 and 47–49 % of maximal oxygen uptake (VO_{2max}). These values obtained from Douglas bags are far from the typical values of 70–80 % VO_{2max} found by the association between heart rate and VO_2 (Bangsbo 2014; Mohr et al. 2005). Moreover, Douglas bags may have limited the participation of players in high-intensity actions such as tackles, duels, and other energy-demanding activities (Stølen et al. 2005). The association between HR and VO_2 reveals that a soccer player may achieve 45–53 mL/kg/min of oxygen uptake during a match (Stølen et al. 2005). The raise in VO_2 leads to an increase in body temperature. In the first half the muscle temperature of vastus lateralis increased from 36 °C (before warm-up) to 39.4 °C (end of first half) and 39.2 °C (end of second half) (Mohr et al. 2004). The core temperature ranges 39–40 °C during the match (Ekblom 1986; Mohr et al. 2004).

The high-intensity that occurs in a match lead to the evidence that in the great majority of time players are rarely below 65 % HRmax, thus suggesting that blood flow to the exercising leg muscles is continuously higher than at rest, which means that oxygen delivery is high (Bangsbo 2014). For that reason, the oxidative capacity of the contracting muscles may be determinant to manage the oxygen kinetics (Bangsbo 2014; Krustrup et al. 2004).

Soccer players may perform 150–250 brief intense actions during a game (Mohr et al. 2003) which indicates that the rate of anaerobic energy turnover is high during specific periods of the game (Bangsbo 2014). The short periods of very high-intensity may indicate the great capacity of creatine phosphate breakdown, which to a great extent is re-synthesized in the following low intensity exercise periods (Bangsbo 1994). Nevertheless, the capacity to slow down after a great effort justifies that after an intense exercise during a game the muscle biopsies revealed 75 % of the level at rest of the creatine phosphate (Krustrup et al. 2006). Despite of the important contribution of ATP-CP system for very fast and powerful actions, the glycolytic system should be also considered during the game. Periods of 5 min of high-intense exertion have been associated with blood lactate concentrations of 12–16 mmol l^{-1} (Krustrup et al. 2006; Mohr et al. 2003). The scientific evidences revealed that after such intense periods there is a 5-min period of intensity lower than the average of the match (Mohr et al. 2003). Moreover, sprint performance is reduced both temporarily during a game and at the end of a soccer game, thus low glycogen levels in individual muscle fibers may explain this evidence (Krustrup et al. 2006).

The inflammatory responses to a soccer match were also studied in elite and notelite male and female soccer players (Souglis et al. 2015). Average relative exercise intensity during the match was similar in male and female players (86.9 ± 4.3 and 85.6 ± 2.3 % HRmax, respectively) and the interleukin 6 and tumor necrosis factor alpha increased 2- to 4-fold above resting values, peaking immediately after the match. Moreover, C-reactive protein and creatine kinase peaked 24 h after the match (Souglis et al. 2015).

In summary, the tactical role and the competitive level affect the high-intensity work done in a soccer game. The intermittent profile of activity and the duration of the match influence the physiological responses of the players. During match, the heart rate may vary between 80 and 90 % HRmax, blood lactate concentration may achieve peaks of 12 mmol l^{-1}, and the VO_2 varies from 36 to 50 mL/kg/min which corresponds to 56–75 % of VO_{2max}. The short but frequent periods of high intensity suggest that the rate of creatine phosphate and glycolysis are frequently used during the game. The great use of muscle glycogen in the majority of the activities conducts to a progressive decrease in intensity and to a change to oxidation of fat by the end of the match.

2.4 Physiological and Physical Profile of Soccer Players

The physical and physiological demands of soccer were briefly described in the previous section. Nevertheless, it is also important to characterize the physiological and physical profile of the players.

Studies conducted in male soccer players reveal VO_{2max} about 50–70 mL/kg/min, whilst the goalkeepers have 50–55 mL/kg/min (Gil et al. 2007a, b; Sporis et al. 2009; Wong and Wong 2009). The anaerobic threshold is reported to be between 76.6 and 90.3 % of HRmax, which are in line with the values found during match play (Stølen et al. 2005). In a study that tested 270 soccer players from the professional first national league of Croatia, it was found that goalkeepers and attackers are the tallest and heaviest players (Sporis et al. 2009). In the same study, it was also found that attackers were the fastest players in 5-, 10- and 20-m sprint (1.39, 2.03, and 3.28 s, respectively). Goalkeepers and attackers had best results in squat jump (46.8 and 44.2 cm, respectively) and countermovement jump (48.5 and 45.3 cm, respectively). Midfielders and defenders had the greatest results in VO_{2max} (62.3 and 59.2 mL/kg/min, respectively) (Sporis et al. 2009).

A study conducted in 241 youth Spanish players (U14 to U21) (Gil et al. 2007a, b) revealed that goalkeepers were the tallest and heaviest players; this pattern has also been reported for mature elite goalkeepers (Arnason et al. 2004). By the other hand, goalkeepers revealed the lowest performance in the endurance tests (Gil et al. 2007a, b). In this particular study conducted in Spain, forwards have the best oxygen intake and the lowest cardiac frequency in the endurance test; moreover also were the fastest players in the 30-m flat and the 30-m with turns of direction (Gil et al. 2007a, b). The nationality of the players may also contribute for different characteristics. A study carried out in elite youth Asian players revealed that these players generate less force, require longer time to reach their peak force, and have a shorter jump height than Tunisian players (Chamari et al. 2004; Wong and Wong 2009). Moreover, it was also found that Asian players are shorter and had a smaller VO_{2max} than Finnish, Tunisian, and US players (Wong and Wong 2009).

Time–motion analysis carried out in female soccer players suggests that they cover 8.5–10 km during a match with an average of 5.7–6.9 km h^{-1} (Krustrup et al.

2005; Mohr et al. 2008). Despite having these smaller values, female players show similar cardiac responses with male players (85–90 % HRmax) (Krustrup et al. 2005). A study that compared players over an 18-year period revealed that 55 mL/kg/min is the standard VO_{2max} for elite female players (Haugen et al. 2014). The range of VO_{2max} may vary from 38.6 to 57.6 mL/kg/min (Jensen and Larsson 1993; Polman et al. 2004).

2.5 Match Analysis on the Game

The match analysis based on notational techniques has helped the characterization of events of soccer. One of the main conclusions is that top teams made more shots and shots of goal than less successful teams (Armatas et al. 2009; Lago-Ballesteros and Lago-Peñas 2010). Top teams also showed better effectiveness, thus they need a lower number of shots to score a goal (Lago-Ballesteros and Lago-Peñas 2010). Moreover, playing at home may guarantee high percentages of winning (50–62 %) (Lago-Peñas and Lago-Ballesteros 2011; Pollard 2006). Moreover, home advantage also increase attack indicators, such as goal scored, total shots, shots on goal, attacking moves, box moves, crosses, assists, passes made, dribbles made, and ball possession (Lago-Peñas and Lago-Ballesteros 2011).

A study carried out in 380 matches of the Spanish soccer League indicated that ball possession can be influenced by situational variables (Lago-Peñas and Dellal 2010). In this study, losing match status was associated with an increase in ball possession in comparison with winning and drawing status (Lago-Peñas and Dellal 2010). Moreover, it was also found that playing away reduces the volume of possession of the ball in comparison with home matches. Finally, this study in Spanish teams also revealed that top-placed teams had a higher percentage of ball possession per match than the less successful teams (Lago-Peñas and Dellal 2010).

The analysis to the shots carried out in 1990 and 1994 FIFA World Cup showed that were made significantly more shots per possession at longer passing sequences than there were at shorter passing sequences for successful teams (Hughes and Franks 2005). Moreover, the authors (Hughes and Franks 2005) also revealed that the conversion ratio of shots to goals is better for direct play than for possession play. Following this evidence, a study conducted in Norway Premier League revealed that counterattacks were more effective than elaborate attacks when playing against an imbalanced defense but not against a balanced defense (Tenga et al. 2010). It was also verified that a defensive balance strategy (tight pressure, present backup, and present cover) was more effective in preventing score-box possessions than the opposite tactics of imbalanced defense (loose pressure, absent backup, and absent cover) (Tenga et al. 2010).

More recently, some studies have been using some algorithms and computational methods to characterize the collective dynamic and organization of the teams (Clemente et al. 2014b). Generally, the studies revealed that players spread their positions during attacking moments and during defensive moments contract their collective organization (close interpersonal distances) (Bartlett et al. 2012; Clemente et al. 2013; Frencken et al. 2011; Moura et al. 2012). Moreover, teams tend to have numerical superiority in their central defensive zones and numerical disadvantage in central attacking zones (Clemente et al. 2015a; Vilar et al. 2013). During attacking moments, teammates tend to provide a greater ratio of coverage in vigilance (line of pass far from men with ball) than cover in support (close line of pass) (Clemente et al. 2014b).

The network analysis carried out during the possession of the ball has been also researched based on graph theory (Duch et al. 2010). The main results showed that most successful teams tend to be more homogeneous and dense in their passes distribution (Clemente et al. 2015b; Grund 2012). On the other hand, great heterogeneity in the passing sequences leads to worse performances (Grund 2012). Independently from tactical lineup, midfielders tend to be the most central player in the team into receive and into perform the passes, thus being the most prominent player in passing sequences (Clemente et al. 2015c; Duch et al. 2010; Peña and Touchette 2012). External defenders tend to be one of the players that most contribute into pass and forwards into received the ball (Clemente et al. 2015a).

2.6 Implications for Training

By having enough information about the physiological, physical, and technical/tactical demands of the soccer it is possible to prescribe the sports training with specificity. This principle of specificity means something more the adequate the physiological stimulus to the game. Running at 85 % HRmax is different from playing soccer game at 85 % HRmax. The muscle participation, the coordination, agility, and fundamentally the decision-making based on the capacity of perceive the environment it is very different. For that reason, training soccer and the specific capabilities of soccer players must be something more than just replies the internal load. For that reason, some studies have been comparing the traditional running methods with specific soccer drills based on the game (small-sided and conditioned games—SSCGs) (Dellal et al. 2008; Hill-Haas et al. 2009). The SSCGs on soccer training aims to ensure the fitness development and at the same time emulate the dynamic of the game.

In a study that compared friendly matches and SSCGs in semi-professional players it was found that the global indicators of workload (distance covered by minute, work: rest ratio, players workload per minute, and exertion per minute) were higher for SSCGs than for friendly matches (Casamichana et al. 2012). The authors suggested that SSCGs lead to greater intensities than friendly matches. Nevertheless, the maximum speed was greater, longer, and more frequent in friendly matches than in SSCGs (Casamichana et al. 2012).

The training with specificity requires emulate the real circumstances of the game. For that reason, SSCGs provides an important contribution for prescribe the exercise and at the same time develop tactical principles and increase the commitment of players with the training session. Nevertheless, to show that SSCGs can be equally efficient than traditional running methodologies for the fitness development it is required data. For that reason, the next chapter will summarize the studies that compared the acute responses and the adaptations that resulted from SSCGs and running-based training programs.

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