Original Article

Analysis of physical load among professional soccer players during matches with respect to field position

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Abstract:

The aim of the study was to assess the level of internal physical load among professional soccer players during training matches and determine differences in size of physical load among field positions (fullbacks, central defenders, wide midfielders, central midfielders, attackers). The screened sample consisted of 13 players of the highest league (average age 23 ± 3.8 years, average body height: 183.1 ± 6.2 cm, average body weight: 74 ± 3.9 kg). Players' physical load was observed during three international training matches with respect to different field positions using Polar Team 2 heart rate monitor. The size of physical load was evaluated according to the level of heart rate and load duration in five zones that were set according to load intensity. These were classified as a zone under the aerobic threshold, zone of aerobic threshold (± 5 beats), zone between aerobic and anaerobic threshold, zone of anaerobic threshold (± 5 beats) and zone over anaerobic threshold. The results showed differences in players' load with regards to their field positions. The highest demands on physical load at high intensity (over anaerobic threshold) were found in central midfielders (21.8 ± 7.8 %) and attackers (17.8 ± 3.8 %). On the contrary, the greatest representation of central defenders was found below aerobic threshold (10.9 ± 3.8 %). Furthermore, results of the study showed that central midfielders spent 61.9 % of total time at, or over, the level of anaerobic threshold. Central defenders spent most time in lowest intensity (zone 1: 10.9 ± 3.8 %). Central midfielders and attackers achieved, in terms of effect size, a significant difference in time spent over the level of anaerobic threshold. The greatest differences between the first and second half-time were found in fullbacks, wide midfielders and central midfielders, while the lowest in central defenders and attackers players. Objectivized results of players' loading are the basis for designing team, group and individual training programmes reflecting the requirements of different field positions.

Key words: football, physical load, heart rate, testing, athletes

Introduction

One of the requirements put on soccer players is to cope with physical load during a match. Physical activity means any movement performed thanks to contracting skeletal muscles. It leads to increased energy expenditure of an individual (Caspersen, Powell, & Christenson, 1985) and is determined by duration, frequency, intensity and type of muscle contraction (Howley, 2001). In sport games, physical activity can be described as repeating short intervals of physical activity at high or maximum intensity, alternating with intervals of lower intensity or physical rest that is regenerative in nature. Thus, in soccer we speak about intermittent load. Hoff and Helgerud (2004) states that individual technique, tactics and physical fitness are important determinants in evaluating differences in soccer performance. The course of a soccer game is variable and a player's performance is influenced by several variables, such as field position (Di Salvo et al., 2007), cultural differences (Rienzi, Drust, Reilly, Carter, & Martin, 2000), level of the game (Mohr, Krstrup, & Bangsbo, 2003), team quality (Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007), exertion (Carling, Espie, Le Gall, Bloomfield, & Jullien, 2010), substitution (Carling et al., 2010), physical fitness level (Krstrup et al., 2003; Maly, Zahalka, & Mala, 2011; Malý, Zahálka, & Malá, 2014; Malý, Zahálka, Malá, Hrásky, & Gryc, 2014) age (Da Silva, Kirkendall, & Neto, 2007; Malý, Zahálka, Malá, et al., 2014) and period of the season (Lehnert, Psotta, Chvojka, & De Ste Croix, 2014). Each player has different physical abilities, technical skills, tactical thinking and psychological characteristics and therefore he has his own role in the team. The coach's task is to use these predispositions in each player (selecting the correct disposition and game system). This leads to an individual approach on the part of the coach regarding the players both in training and real matches (Bangsbo, 1995). The players perform high intensity running over short distances with focus on quick restoration of the body in a short period. In a soccer match, which is characterized by intermittent physical load, high demands are put on aerobic capacity. Some authors (Bangsbo, 1994; Mohr et al., 2003) reported that players are able to run 9

– 12 km during a match. High load intensity is a crucial element distinguishing players of elite and lower levels. Elite level players perform 2 – 3 km higher in running intensity (> 15 km/h) and 0.6 km in sprint (> 20 km/h) (Iaia, Rampinini, & Bangsbo, 2009). The rest of the match, which accounts for approximately 80 – 90 % of performance, is made up of lower or medium activities (Bangsbo, 1994; Rienzi et al., 2000). Mohr et al. (2003) reports, in professional players, that central defenders cover smaller total distances and perform fewer high intensity runs during the match in comparison to players in other field positions. Compared with a central defender, fullbacks perform much more sprints and their total covered distance is performed at high intensity. Attackers cover a total distance at similar intensity to fullbacks. The number of sprints in attackers is considerably greater than in midfielders or defenders and their total covered distance is smaller, too. Midfielders undergo similar physical load during the match as fullbacks and attackers, in terms of intensity, however, total covered distance is greater and number of sprints lower (Bangsbo, 1994; Bangsbo, Norregaard, & Thorso, 1991). There are also individual differences among players of the same playing positions in the same team (Mohr et al., 2003).

The main aim of the study was to find out the level of internal physical load of elite soccer players during a training match and to detect differences among the field positions from the perspective of their load during the game.

Material & methods

Participants

The screened sample was composed of elite professional soccer teams (the winner of the Czech soccer league, $n = 13$, age = 23 ± 3.8 years, body height = 183.1 ± 6.2 cm, body mass = 74 ± 3.9 kg). Table 1 shows the characteristics of the tested group in terms of field positions. Measurement was carried out during friendly international matches during the close season with elite European level opponents.

Table 1. Basic characteristics of the players in all three matches

Field position	F	Cd	Wm	Cm	A
Age (years)	22±2.1	25±3.6	22±1.7	25±1.5	27±7.2
Body height (cm)	183±1.7	188±1.4	180±0.6	181±2.6	183±3.5
Body weight (kg)	74±3.5	79±3.2	73±3.5	75±0.6	77±4.0

Note: F – fullback, Cd – central defender, Wd – wide midfielder, Cm – central midfielder, A – attacker

Methods of data collecting and processing

Measurement was carried out during an official friendly match on natural grass between 6 – 8^{pm}. Air temperature was 24 – 27 °C. Differences in levels of physical load were observed with respect to field positions: fullbacks (F), central defenders (Cd), wide midfielders (Wm), central midfielders (Cm), and attackers (A). A condition for inclusion into research was to have played at least 2 whole matches without substitution. The level of physical effort was assessed using heart rate and time spent in individual 5 zones (1: zone under aerobic threshold (AET), 2: zone of aerobic threshold in the interval of ± 5 beats, 3: zone between aerobic and anaerobic threshold (ANT), 4: zone of anaerobic threshold in the interval of ± 5 beats and 5: zone over anaerobic threshold). Calculating the average maximum heart rate and movement in individual zones was carried out using Polar Team 2 (Polar Electro Oy, Kempele, Finland), which is intended mainly for online and offline measurement of heart rate, especially in team sports. Its advantage in comparison to traditional sport testers is that the measured athlete only wears a chest strap. Soccer rules do not allow players to wear anything else apart from kit. For exact identification of AET, ANT and VO_{2max} , the subjects were measured on a treadmill in a test up to vita maximum in the laboratory. These data were essential for saving in sport testers of individual players. The research was approved by the Ethical Committee of the Faculty of Physical Education and Sports at Charles University in Prague. Measurements were carried out in accordance with the ethical standards of Declaration of Helsinki and ethical standards in sport and exercise science research (Harriss & Atkinson, 2011).

Statistical analysis

Collected data were subjected to descriptive analysis and effect size analysis. From methods of descriptive statistics we used the mean as a measure of central tendency and standard deviation and standard error of the mean as measures of variability. Effect size was determined using Cohen's "d" coefficient which was calculated as the difference of the means of the individual groups of data divided by the pooled standard deviation [1] (Thomas & Nelson, 2001). Effect size was estimated according to (Cohen, 1992) who presents that $d < 0.5$ indicates small, $d = 0.5 - 0.8$ medium and $d > 0.8$ large effect size.

$$d = \frac{x_1 - x_2}{s} \quad s_p = \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}} \quad [1]$$

Statistical analysis was carried out using SPSS version 19 (StatSoft, USA) software.

Results

Research results are presented in Table 2 and Fig. 1-5. In the first half-time, players in all field positions had higher heart rate in comparison to the second half. The greatest differences between the first and second half-time were found in F, Wm and Cm, while the smallest differences in Cd and A.

The greatest demands on physical activity at high intensity (over the ANT) were achieved by Cm (21.8 ± 7.8 %) and A (17.8 ± 3.8 %). On the contrary, the greatest proportion below AET was found in Cd (10.9 ± 3.8 %).

Table 2. The heart rates values during the match with respect to field positions

Field position	Fb	Cd	Wm	Cm	A
HR first half (beat/min)	169 $\pm$ 2.5	168 $\pm$ 3.1	163 $\pm$ 2.5	173 $\pm$ 4.2	160 $\pm$ 1.7
HR second half (beat/min)	162 $\pm$ 4.2	164 $\pm$ 4.5	157 $\pm$ 2.5	166 $\pm$ 4.6	157 $\pm$ 5.1
Average HR in match (beat/min)	165 $\pm$ 3.1	166 $\pm$ 4.0	160 $\pm$ 2.5	170 $\pm$ 4.6	159 $\pm$ 2.5
Maximal HR in match (beat/min)	181 $\pm$ 3.5	184 $\pm$ 4.5	179 $\pm$ 3.1	187 $\pm$ 3.8	178 $\pm$ 2.5
Time in Zone 1 (%)	9.1 $\pm$ 5.3	10.9 $\pm$ 3.8	10.2 $\pm$ 1.2	8.9 $\pm$ 2.9	7.6 $\pm$ 3.1
Time in Zone 2 (%)	15.3 $\pm$ 3.8	26.4 $\pm$ 1.1	23.8 $\pm$ 3.1	10.7 $\pm$ 3.1	19.6 $\pm$ 8.0
Time in Zone 3 (%)	30.9 $\pm$ 1.6	34.0 $\pm$ 4.0	36.6 $\pm$ 8.2	18.2 $\pm$ 2.0	21.1 $\pm$ 4.1
Time in Zone 4 (%)	37.6 $\pm$ 4.4	21.9 $\pm$ 0.7	16.7 $\pm$ 9.8	39.6 $\pm$ 1.8	32.2 $\pm$ 11.3
Time in Zone 5 (%)	6.9 $\pm$ 3.8	6.6 $\pm$ 6.2	13.1 $\pm$ 0.9	21.8 $\pm$ 7.8	17.8 $\pm$ 3.8

Note: F – fullbacks, CD – central defenders, WM – wide midfielders, CM – central midfielders, A – attackers, HR – heart rate

Fig. 1. Relative time spending in different zones in fullbacks during the match

Fig. 2. Relative time spending in different zones in central defenders during the match

Fig. 3. Relative time spending in different zones in wide midfielders during the match

Fig. 4. Relative time spending in different zones in wide midfielders during the match

Fig. 5. Relative time spending in different zones in wide midfielders during the match

From the perspective of Cohen's coefficient of effect size, in all matches we recorded significant effect size between observed field position (Tables 3 – 5).

Table 3. Low effect size among the monitored field positions (column vs. row)

Field position	Fb	Cd	Wm	Cm	A
HR first half (beat/min)	Cd	Fb			
HR second half (beat/min)	Cd	Fb,Cm	A	Cd	Wm
Av. HR in match (beat/min)	Cd	Fb	A		Wm
Max. HR in match (beat/min)			A		Wm
Time in Zone 1 (%)	Cd,Wm,Cm,A	Fb,Wm	Fb,Cd	Fb,A	Fb,Cm
Time in Zone 2 (%)					
Time in Zone 3 (%)		Wm	Cd		
Time in Zone 4 (%)	A				Fb
Time in Zone 5 (%)	Cd	Fb			

Note: F – fullbacks, CD – central defenders, WM – wide midfielders, CM – central midfielders, A – attackers, HR – heart rate

Table 4. Medium effect size among the monitored field positions (column vs. row)

Field position	Fb	Cd	Wm	Cm	A
HR first half (beat/min)					
HR second half (beat/min)					
Av. HR in match (beat/min)					
Max. HR in match (beat/min)	Cd,Wm	Fb,Cm	Fb	Cd,	
Time in Zone 1 (%)		Cm	Cm,	Cd,Wm	
Time in Zone 2 (%)	A		A		Fb,Wm
Time in Zone 3 (%)					
Time in Zone 4 (%)	Cm	Wm	Cd	Fb	
Time in Zone 5 (%)				A	Cm

Note: F – fullbacks, CD – central defenders, WM – wide midfielders, CM – central midfielders, A – attackers, HR – heart rate

Table 5 High effect size among the monitored field positions (column vs. row)

Field position	Fb vs.	Cd	Wm	Cm	A
HR first half (beat/min)	Wm,Cm,A	Wm,Cm,A,	Fb,Cd,Cm,A	Fb,Cd,Wm,A	Fb,Cd,Wm,Cm
HR second half (beat/min)	Wm,Cm,A	Wm,A,	Fb,Cd,Cm,	Fb,Wm,A	Fb,Cd,Cm
Av. HR in match (beat/min)	Wm,Cm,A	Wm,Cm,A,	Fb,Cd,Cm,	Fb,Cd,Wm,A	Fb,Cd,Cm
Max. HR in match (beat/min)	Cm,A	Wm,A,	Cd,Cm,	Fb,Wm,A	Fb,Cd,Cm
Time in Zone 1 (%)		A,	A		Cd,Wm
Time in Zone 2 (%)	Cd,Wm,Cm,	Fb,Wm,Cm,A	Fb,Cd,Cm,	Fb,Cd,Wm,A	Cd,Cm
Time in Zone 3 (%)	Cd,Wm,Cm,A	Fb,Cm,A	Fb,Cm,A	Fb,Cd,Wm,A	Fb,Cd,Wm,Cm
Time in Zone 4 (%)	Cd,Wm,	Fb,Cm,A	Fb,Cm,A	Cd,Wm,A	Cd,WmCm
Time in Zone 5 (%)	Wm,Cm,A	Wm,Cm,A,	Fb,Cd,Cm,A	Fb,Cd,Wm,	Fb,Cd,Wm

Note: F – fullbacks, CD – central defenders, WM – wide midfielders, CM – central midfielders, A – attackers, HR – heart rate

Dicussion

In the presented study, we focused on determining physical load among soccer players in terms of their field positions. To assess the size of physical load, we used TeamPolar2 online system and on the basis of different load zones we observed time spent in each zone. Results showed greater physical activity in the first half-time than in the second. In the second half, heart rate decreased by 9 beats. This decrease is particularly attributed to fatigue.

High-intensity load leads to fatigue and decrease in physical performance of the player at the end of match. This phenomenon is ascribed to the depletion of muscle glycogen, reductions in circulating blood glucose, hyperthermia and the progressive loss of body fluids (Mohr, Krstrup, & Bangsbo, 2005). The cause of fatigue at the end of match can be the depletion of glycogen in individual muscle fibres. Designing nutritional strategy and training plan is important for increasing muscle glycogen before the game. In the training session before the match, we have to take into account the minimum reduction of muscle glycogen (Bangsbo, Iaia, & Krstrup, 2007). Fatigue starts to accumulate towards the end of game, when the number of high intensity activities decreases (Krstrup et al., 2006; Mohr et al., 2003, 2005). The most significant decrease of high intensity was observed in the last 15 minutes of the match (Mohr et al., 2003; Rienzi et al., 2000). In terms of time of load in individual zones, players spent most time in the zone 4 (ANT $\pm$ 5 beats). These results were detected in all field positions, apart from Cd and Cm, who spent most time in the zone 3 (AET – ANT). In a soccer match, energy is predominantly provided by aerobic metabolism, which is, however, in high intensity activities during the game overlapped by anaerobic metabolism (Mohr et al., 2003; Wragg, Maxwell, & Doust, 2000). High intensity activities in soccer, which put demands on anaerobic metabolism, include sprints (various distances and duration), jumps or one against one play. However, during short high intensity movement there is no high response in the form of increased heart rate at the level of ANT. On the other hand, repeated intensive activities are one of the decisive factors of the game result (Wragg et al., 2000). Elite players undertake from 150 to 250 high intensity activities in a match (Krstrup et al., 2006). High intensity activities can be influenced by the opponent's quality, current score or player's fatigue. In comparison to the results by Bangsbo (2005), who report values of load for elite soccer in a competition game, we can state that our players took place approximately at the same level of average heart rate than other professional players in the same category. Average literature presents that, during the match, average HR in all defenders is 155 bpm and in midfielders and attackers it is 170 bpm (Van Gool, Van Gerven, & Boutmans, 1988). Other authors (Ali & Farrally, 1991) reports values of HR generally for all players as 169 bpm in a match. The some researcher reported that average heart rate during the match is approximately 85 % of HR_{max} and maximum heart rate is about 98 % of HR_{max} (Ali

& Farrally, 1991; Bangsbo, 1994; Krstrup, Mohr, Ellingsgaard, & Bangsbo, 2005). Heart rate during a (common) match featuring elite players does not decrease under 65 % of HR_{max} (Krustup, Hellsten, & Bangsbo, 2004). A very important factor in a player's performance during a match is the ability to repeatedly perform intermittent, high intensive activity (Krustup et al., 2005; Mohr et al., 2003, 2005). Player's load is in terms of time asynchronous and irregular. To maintain the highest possible intensity during the match, the ability of fast recovery processes is essential. Teplan et al. (2012) report a higher level of recovery processes (6.5%) in elite players in comparison to the players of lower performance level. This parameter may be an indicator of fitness capacity and specific adaptation of a player on intermittent load in the match. Mohr et al. (2003) state that players' performance throughout the match decreases after high intensity activities which results in fatigue and exhaustion. Efficiency of recovery processes after short high-intensity physical activity can be a prerequisite for performing physical activity throughout the whole game. One of the main indicators of the speed of recovery processes and general endurance is the level of maximum oxygen uptake (VO_{2max}). In our case, central midfielders achieved the highest values spent in the last two zones 4 (39.6 ± 1.8 %) and 5 (21.8 ± 7.8 %). Tumilty (1993) and Wisloff, Helgerud, and Hoff (1998) reported that, from the perspective of field position, the greatest demands on VO_{2max} are put on midfielders because during the match they have the largest action radius in the field. Their task is to control a transition phase (from the defensive phase to the offensive and vice versa) and thus support teammates in their offensive and defensive activities. Results of the study revealed that central midfielders spent 61.9 % of total time at, or over, the level of ANT. These values are, however, lower in comparison to the study by Stratton, Reilly, Williams, and Richardson (2004) who report that adult players spend 66 % of the match in the anaerobic zone and 34 % of the match in the aerobic zone. Billows, Reilly, and George (2005) reported that young players spend 63 % of the match in the anaerobic zone and 37 % of the match in the aerobic zone, respectively. The level of physical load varies in individual players according to their field positions. Each player has his specific function and role, which compose prerequisites to deal successfully with playing tasks. For instance, central defenders cover the shortest distance and perform the lowest number of high intensity runs during the match (Bradley et al., 2009; Mohr et al., 2003; Rampinini et al., 2007), on the contrary, fullbacks and attackers perform significantly ($p < 0.05$) longer sprints than central defenders and midfielders (Mohr et al., 2003). In our research, central defenders spent most of time in the lowest intensity (Zone 1, 10.9 ± 3.8 %). Central midfielders and attackers achieved in terms of effect size a significant difference in time spent over the level of anaerobic threshold.

Conclusions

The study presents the size of physical load of professional players at the highest level in the Czech Republic during the match. Results showed differences in players' load depending on each player's field position. Central defenders spent less time at the level of anaerobic threshold in comparison to wide midfielders. Central midfielders and attackers showed the highest values spent over the level of anaerobic threshold, which are significantly higher in comparison to other field positions. Results also revealed a significant effect of player's load in relation to the first and second half, which is believed to be caused by fatigue and gradual depletion of player's energy reserves. Objectivized results of players' loading are the basis for designing team, group and individual training programmes reflecting the requirements of different field positions. Each field position is characterized by its own movement profile and different tactical requirements in relation to the ball; furthermore, there are different requirements for fitness level, physiological and bio-energetic expenditure as well as psychological parameters. In further research, it is necessary to monitor the response of internal load (heart rate) simultaneously with external load (time motion analysis) in a competition match at the elite level of both domestic and international competitions.

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