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Positional differences in the cardiorespiratory, autonomic, and somatic profiles of professional soccer players

Martin Semjon[1], Michal Botek[1,*], Zbyněk Svozil[1], and Andrew J. McKune[2,3]

[1]Faculty of Physical Culture, Palacký University Olomouc, Olomouc, Czech Republic; [2]Discipline of Sport and Exercise Science, Faculty of Health, Research Institute for Sport and Exercise, University of Canberra, Canberra, Australia; and [3]Discipline of Biokinetics, Exercise and Leisure Sciences, School of Health, University of KwaZulu-Natal, Durban, South Africa

Background: In order to optimize training in soccer, knowledge about the specific position fitness demands and characteristics is required. **Objective:** The aim of the study was to determine whether there are position specific differences in somatic, cardiorespiratory and autonomic cardiac profiles of professional senior Czech soccer players. **Methods:** All players (N = 120) were divided into six groups according to field positions: goalkeeper (GK; n = 11), external defenders (ED; n = 15), central defenders (CD; n = 18), external midfielders (EM; n = 18), central midfielders (CM; n = 24) and forwards (F; n = 34). Players underwent anthropometrical and heart rate variability (HRV) assessment, and a maximal incremental running test in order to obtain maximal oxygen uptake (VO_2max) and heart rate. HRV variables were transformed using the natural logarithm (Ln). **Results:** GK and CD were significantly (p = .005) heavier than ED, EM, CM, and F; while F were significantly (p = .026) heavier than CM and EM. GK and CD were significantly (p = .008) taller than ED, EM, CM, F; and EM were significantly (p = .041) shorter than CM and F. The only significant (p = .043) difference in percentage of body fat was observed in CD compared with CM. A significantly (p = .021) lower VO_2max was observed for GK compared with ED, CD, EM, CM, and F. Supine HRV was significantly (p = .039) lower for Ln LF/HF in GK compared with F. Standing HRV was significantly (p = .03) lower for Ln LF in CD compared with both ED and F, significantly (p = .028) higher for Ln LF/HF in ED compared with CD and EM. **Conclusions:** In soccer, specific positions are associated with different height, body mass and aerobic capacity. A lower VO_2max and vagal activity in GK compared with other playing positions may not be considered as disadvantage for performance in this specific playing position.

Keywords: maximal oxygen uptake, vagal activity, body composition, heart rate variability

Introduction

Elite performance in soccer represents a composite of high level physical performance characteristics that, in turn, depend upon a variety of anthropometrical and physiological properties, as well as on the training and health status of the individual athlete (MacArthur & North, 2005). In soccer, is well known that different field positions require specific fitness characteristics (Magalhães Saleset al., 2014; Stølen, Chamari, Castagna, & Wisløff, 2005; Wisløff, Helgerud, & Hoff, 1998). Therefore, identifying each player's specialized position has been suggested to be important. Such a process will help optimize their physical, physiological, psychological, technical and tactical development in order to prepare them for higher playing levels later in their career (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Strøyer, Hansen, & Klausen, 2004).

Soccer is an aerobic sport that also places demands on the anaerobic energy system for speed endurance, strength, speed and explosiveness (dos Santos et al., 2014; Strøyer et al., 2004). VO_2max values for professional soccer players that play in the Champions League range between 60–65 $ml \cdot kg^{-1} \cdot min^{-1}$ (Helgerud, Rodas, Kemi, & Hoff, 2011).

From different playing position point of view, central defenders (CD) spend significantly more time walking and jogging (0–11 $km \cdot h^{-1}$) during matches and also spend the least time in all other work-intensities

* Address for correspondence: Michal Botek, Department of Natural Sciences in Kinanthropology, Faculty of Physical Culture, Palacký University Olomouc, třída Míru 117, 771 11 Olomouc, Czech Republic. E-mail: michal.botek@upol.cz

and cover the least distance (Di Salvo et al., 2007). In contrast, midfield players, such as central midfielders (CM) and external midfielders (EM), spend the shortest amount of time walking and jogging, but covered the most distance at low and moderate running speeds. EM spent the most amount of time and cover the most distance at high-running speeds and sprinting (Rampinini, Sassi, Sassi, & Impellizzeri, 2004).

Body composition, anthropometric dimensions, and morphological characteristics play vital roles in determining the success of a soccer player (Keogh, 1999; Silvestre, West, Maresh, & Kraemer, 2006). Accurate evaluation of these parameters is required to identify specific characteristics that are a necessity for optimal soccer performance which in turn may influence player selection (Gil, Ruiz, Irazusta, Gil, & Irazusta, 2007). Authors investigating body fat (BF) in different field positions in soccer (Reilly, 1996) found small differences in percent BF among the outfield positions, although midfielders tended to have lower BF levels.

Spectral analysis (SA) of RR intervals to determine heart rate variability (HRV) is accepted as a non-invasive method for autonomic cardiac regulation assessment (Akselrod et al., 1981). It is well known that orthostatic stress decreases vagal activity and stimulates sympathetic activity (Eckberg, 1997; Malliani, Pagani, Lombardi, & Cerutti, 1991), whereas clinostasis stimulates vagal activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Therefore, to enhance the sensitivity of measuring small reciprocal changes in the vagal and sympathetic pathways in elite athletes it has been suggested that HRV should be quantified from electrocardiogram (ECG) sampling in both standing and supine positions (Botek, McKune, Krejčí, Stejskal, & Gába, 2014).

Endurance training has been shown to induce a decline in resting heart rate (HR_{rest}), as well as increase overall resting HRV as a result of elevated parasympathetic (vagal) activity (Aubert, Seps, & Beckers, 2003; Carter, Banister, & Blaber, 2003; Hedelin, Wiklund, Bjerle, & Henriksson-Larsén, 2000; Kouidi, Haritonidis, Koutlianos, & Deligiannis, 2002). Vagal activity dominance allows athletes to recover faster and accelerate the transition from catabolism to anabolism (Hautala et al., 2001).

Both, high frequency (HF) oscillations in RR intervals (Pichot et al., 2000), and a root of the mean square of successive differences (Buchheit, 2014) have been suggested to reflect the cardiac vagal outflow, while reciprocal changes between vagal and sympathetic activity are evaluated via analysis of low frequency power (LF) (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996) and LF/HF (Ori, Monir, Weiss, Sayhouni, & Singer, 1992), respectively.

The main aim of this study was to assess whether different playing positions in soccer require specific somatic, aerobic and HRV characteristics among Czech professional soccer players.

Methods

Participants

This study included 164 soccer players from clubs that play in the first division of the senior Czech Republic Soccer League. These players had undergone preseason laboratory testing between 2009 and 2014. One hundred and twenty players performed all the preseason measurements (anthropometrical evaluation, HRV, maximal incremental running test to determine maximal aerobic capacity), while 44 players only performed the incremental running test, and were therefore included for the cardiorespiratory performance analysis only.

Inclusion criteria for participation in this study were the following – each player should: 1) participate in the entire laboratory testing protocol; 2) be free of any health complications that may limit performance in any laboratory test, especially the maximal incremental running test; 3) be a member of the senior team squad at the time of testing. The study was approved by the Ethics Committee of the Faculty of Physical Culture, Palacký University Olomouc. All of the subjects participating in the study were volunteers and had given their written informed consent.

Testing procedures

The entire testing protocol was performed between 8–12 a.m. on a single day in following order – a resting autonomic cardiac activity assessment; basic anthropological measurement; and maximal incremental running test. For the focus of the current paper, only age and data related to anthropometry, autonomic cardiac activity and aerobic endurance capacity were included.

Autonomic cardiac activity assessment

The monitoring of autonomic cardiac activity was performed between 8–12 a.m. in a laboratory where the ambient temperature ranged from 22 to 24° C. During the measurement, each player was shielded against acoustic and visual disturbances. To determine the resting HR and HRV variables, the ECG signal was measured at a sampling frequency of 1000 Hz using VarCor PF7 (DIMEA Group, Olomouc, Czech Republic). The ECG sampling was performed during an orthoclinostatics maneuver (supine-standing-supine) up to January 2013, and in the following period, a time-modified orthoclinostatics test was used, because both orthoclinostatics challenges provide comparable HRV results (Botek, Krejčí, Neuls, & Novotný, 2013).

The ECG record was examined and all premature ventricular contractions, missing beats and any artefacts, were manually filtered. A set of 300 artefact-free subsequent RR intervals was obtained from each phase. Spectral analysis of HRV was used to assess the autonomic cardiac activity and was performed using the Fast Fourier Transform. Two frequency bands were analyzed – the HF power (0.15 to 0.50 Hz) that is thought to represent respiratory related cardiac vagal activity (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996); and the LF power (0.05 to 0.15 Hz) that is considered to exhibit baroreflex activity together with sympathetic and vagal outflow (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996) whereas the LF/HF ratio reflects the sympathovagal balance (Ori et al., 1992). A time domain variable, the root mean square of successive difference in RR intervals (rMSSD) was also used. rMSSD is regarded as an index of vagal activity (Buchheit, 2014) that is thought to be resistant to the effects of breathing frequency (Penttilä et al., 2001).

Anthropometrical measurement

The soccer players had their body height and body mass measured using the SOEHNLE 7307 (Leifheit, Nassau, Germany). The % BF was determined using bioimpedance analysis (Tanita BC-418 MA, Tanita, Tokyo, Japan).

Maximal incremental running test

Each soccer player underwent a graded maximal stress test on a treadmill (Lode Valiant, Lode, Groningen, Netherlands) in order to obtain VO_2max and HR_{max}. The exercise protocol consisted of a 4 minute warm-up period (2 minutes at 8 $km \cdot h^{-1}$ with a 0% inclination and a further 2 minutes at the same speed with a 5% inclination). The speed was then increased to 10 $km \cdot h^{-1}$ for 1 minute with the gradient kept at 5%. For each minute thereafter speed increased by 1 $km \cdot h^{-1}$ with the gradient at 5% up to maximal speed of 16 $km \cdot h^{-1}$. From this stage only inclination increased by 2.5% every minute until exhaustion. Breath-by-breath ventilation and gas exchange were continuously analyzed (Ergostik, Geratherm Respiratory, Bad Kissingen, Germany) during the exercise with the data averaged to 30 seconds for analysis. The following criteria were used to document that VO_2max was achieved: 1) a lack of increase in VO_2 upon an increase in work rate, 2) respiratory exchange ratio > 1.10 (Shephard & Åstrand, 1992) and 3) a HR_{max} higher than 85% of age-predicted value (HR_{max} = 220 – age). VO_2max was recorded as the highest oxygen consumption value in the final 30 seconds of the test. HR responses (Polar Wind Link+PolarH3, Polar, Kempele, Finland) were monitored continuously during the maximal stress test.

Statistical analysis

The subjects ($N = 120$) were divided into six groups according to field position: GK ($n = 11$), ED ($n = 15$), CD ($n = 18$), EM ($n = 18$), CM ($n = 24$), and F ($n = 34$). A one-way analysis of variance (ANOVA) with Fisher's LSD post-hoc test was used to evaluate the differences between player positions. Due to the HRV variables demonstrating abnormal distribution, a natural logarithm (Ln) was applied. After Ln-transformation, all HRV variables were normally distributed. Statistical analyses were performed using STATISTICA (Version 12.0; StatSoft, Tulsa, OK, USA) with $p < .05$ considered statistically significant.

Results

Player descriptive statistics and ANOVA results for anthropometric, aerobic capacity and HRV variables are shown in Table 1 and 2. Based on the ANOVA result (Table 1) there was a significant age difference ($p = .025$) between CD and F. GK and CD were significantly ($p = .005$) heavier than ED, EM, CM, and F; while F were significantly ($p = .026$) heavier than CM and EM. GK and CD were significantly ($p = .008$) taller than ED, EM, CM, F; and EM were significantly ($p = .041$) shorter than CM and F. The only significant ($p = .043$) difference in % BF was observed in CD compared with CM.

Based on the ANOVA result (Table 1), VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) was significantly ($p = .021$) lower for GK compared with ED, CD, EM, CM, F. There were no significant differences in HR_{rest} ($b \cdot min^{-1}$) among all groups.

Spectral analysis of HRV was assessed in the standing and supine positions. Based on the ANOVA results (Table 2), there were significant differences between the playing positions for a few HRV variables. Standing LnLF was significantly ($p = .030$) lower for CD compared with ED and F. Standing Ln LF/HF was significantly ($p = .028$) higher for ED compared with CD and EM. GK exhibited significantly ($p = .039$) lower supine Ln rMSSD compared with F.

Table 1
Anthropometric and cardiorespiratory values according to playing positions (mean ± SD)

	GK	ED	CD	EM	CM	F
Part 1 (N = 120)						
n	11	15	18	18	24	34
Age (years)	26.6 ± 6.5	26.7 ± 4.8	27.3 ± 6.2[a]	25.3 ± 4.2	25.8 ± 5.3	24.0 ± 3.6
Body mass (kg)	87.0 ± 4.6[b]	76.5 ± 4.8	84.5 ± 4.6[b]	74.6 ± 5.1	75.8 ± 6.3	79.4 ± 7.7[c]
Body height (cm)	188.6 ± 3.3[d]	180.7 ± 3.6	187.9 ± 4.9[d]	177.6 ± 4.4[e]	181.2 ± 5.8	183.3 ± 7.2
Body fat (%)	11.5 ± 3.1	11.2 ± 2.4	11.7 ± 2.8[f]	10.3 ± 2.1	9.9 ± 2.9	10.4 ± 3.1
Part 2 (N = 164)						
n	21	20	23	23	31	46
HR_{rest} ($b \cdot min^{-1}$)	52.0 ± 8.8	51.4 ± 6.5	50.6 ± 8.0	52.6 ± 7.5	52.8 ± 10.6	51.1 ± 7.5
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	54.0 ± 3.4[g]	58.7 ± 4.1	58.0 ± 6.1	60.2 ± 4.7	59.3 ± 4.5	58.5 ± 3.5

Note. GK = goalkeepers; ED = external defenders; CD = central defenders; EM = external midfielders; CM = central midfielders; F = forwards. HR_{rest} = resting heart rate; VO_2max = maximal oxygen consumption. [a]denotes significant difference ($p < .05$) from F; [b]denotes significant difference ($p < .05$) from ED, EM, CM, F; [c]denotes significant difference ($p < .05$) from CM and EM; [d]denotes significant difference ($p < .05$) from ED, EM, CM, F; [e]denotes significant difference ($p < .05$) from CM and F; [f]denotes significant difference ($p < .05$) from CM; [g]denotes significant difference ($p < .05$) from ED, CD, EM, CM, F.

Table 2
Values of SA HRV according to playing positions (mean ± SD; N = 120)

	GK (n = 11)	ED (n = 15)	CD (n = 18)	EM (n = 18)	CM (n = 24)	F (n = 34)
Standing position in orthoclinostatic maneuver						
Ln LF (ms^2)	6.53 ± 1.29	7.07 ± 0.80	6.26 ± 1.19[a]	6.62 ± 1.01	6.79 ± 0.77	6.90 ± 0.97
Ln HF (ms^2)	5.12 ± 1.71	5.12 ± 1.29	5.13 ± 1.16	5.42 ± 1.20	5.18 ± 0.95	5.39 ± 1.13
Ln LF/HF (ms^2)	1.40 ± 1.62	1.95 ± 0.97[b]	1.13 ± 1.09	1.20 ± 0.93	1.61 ± 0.61	1.51 ± 0.83
Ln rMSSD (ms)	3.07 ± 0.77	3.31 ± 0.51	3.08 ± 0.65	3.23 ± 0.49	3.25 ± 0.48	3.28 ± 0.58
Supine position in orthoclinostatic maneuver						
Ln LF (ms^2)	6.44 ± 1.05	6.66 ± 1.26	6.42 ± 1.09	6.71 ± 1.08	6.14 ± 0.98	6.24 ± 1.22
Ln HF (ms^2)	6.80 ± 1.31	7.37 ± 0.89	7.24 ± 0.97	7.49 ± 1.03	7.23 ± 1.01	7.40 ± 0.97
Ln LF/HF (ms^2)	−0.37 ± 0.85	−0.71 ± 0.84	−0.82 ± 1.06	−0.78 ± 0.93	−1.09 ± 1.26	−1.16 ± 1.23
Ln rMSSD (ms)	4.12 ± 0.64[c]	4.43 ± 0.45	4.32 ± 0.54	4.42 ± 0.56	4.34 ± 0.57	4.44 ± 0.47

Note. GK = goalkeepers; ED = external defenders; CD = central defenders; EM = external midfielders; CM = central midfielders; F = forwards. Ln LF = natural logarithm of low-frequency power; Ln HF = natural logarithm of high-frequency power; Ln LF/HF = natural logarithm of low-frequency/high-frequency ratio; Ln rMSSD = natural logarithm of root mean square successive difference of RR intervals. [a]denotes significant difference ($p < .05$) from ED and F; [b]denotes significant difference ($p < .05$) from CD and EM; [c]denotes significant difference ($p < .05$) from F.

Discussion

The present study is the first report the anthropometric, cardiorespiratory and HRV characteristics of professional players in the senior Czech Republic Soccer League. The study evaluated whether these variables differ amongst playing positions. The primary findings of this study were that a) GK and CD were significantly heavier and taller than ED, EM, CM, and F; b) there are no significant differences in cardiorespiratory performance and vagal activity among outfield players, and c) GK demonstrated a lower values of VO_2max together with lower cardiac vagal activity compared with other playing positions.

In the present study, the players were divided into six different groups according to their field positions. Currently, the trend in world soccer is for an increase in average body height (Joksimović, Smajić, Molnar, & Stanković, 2009). Compared with a number of other nations the Czech players are taller on average. Specifically, they are 5.4 cm taller than players in the United Arab Emirates elite League (Magalhães Sales et al., 2014), as well as taller than players in the Croatian League (Matković, Janković, Ružić, & Leko, 2003) and the Northern Irish League (Wilson & O'Donoghue, 2005). However, players from the English Premier League are of similar height (Milsom et al., 2015) to the Czech players. Unsurprisingly, relating to the specific requirements of their positions, the tallest and heaviest players in the present study were the GK and the CD (advantage in the air on defense), while the shortest were the EM (agility advantage). These results are supported by previous research (Di Salvo et al., 2007; Ekblom, 1986; Magalhães Sales et al., 2014; Matković et al., 2003; Rampinini et al., 2004; Milsom, et al., 2015; Sutton, Scott, Wallace, & Reilly, 2009). There were also significant differences in body mass between the external and central positions. This result was in contrast to other studies where differences between the central and external positions were not found (Carling & Orhant, 2010; Michailidis et al., 2013).

The mean of percentage in BF (% BF) in the players was 10.7 ± 2.8% that is similar to the values reported Le Gall, Carling, Williams, and Reilly (2010). In addition, we found a significant difference in % BF only between CD and CM. Some researchers (Carling & Orhant, 2010; Michailidis et al., 2013) reported a higher % BF in EM compared with other positions.

Aerobic performance represented by VO_2max is regarded as an important physiological parameter for optimal performance (Casajus, 2001). Elite soccer players have been reported to achieve values in the range of 55–70 $ml \cdot kg^{-1} \cdot min^{-1}$ (Stølen et al., 2005). In this study, there were no differences in VO_2max between the outfield positions, however, the GK had significantly lower VO_2max values compared with the other positions. The difference in VO_2max between the GK and outfield players was in the range of 4.0 to 6.2 $ml \cdot kg^{-1} \cdot min^{-1}$. The difference could be explained by different training emphasis and match loads. In a previous study, compared with the present study, players achieved a VO_2max that was 6.0 $ml \cdot kg^{-1} \cdot min^{-1}$ higher per position (Magalhães Sales et al., 2014). However, in contrary to our research, Magalhães Sales et al. (2014) obtained their VO_2max values indirectly based on an equation. Thus, we feel that a large discrepancy in VO_2max level between studies was due to methodological inconsistency. Although it has been recommended that players should have VO_2max values greater than 60 $ml \cdot min^{-1} \cdot kg^{-1}$ to be competitive at the highest level (Reilly, Bangsbo, & Franks, 2000), in the present study, only the EM achieved this value. However, anaerobic power and capacity are also important in soccer (Stølen et al., 2005; Wisløff et al., 1998). Therefore VO_2max values should be viewed alongside speed, agility, power, and repeat sprint ability for a more appropriate assessment (Stølen et al., 2005; Wisløff et al., 1998).

Although we found no significant differences in vagal activity, represented by Ln HF (Aubert et al., 2003), the highest Ln HF was demonstrated in EM who also had the highest VO_2max value. It has been reported that inter individual variation in adaptation to aerobic training may depend on baseline ANS activity level, particularly vagal activity (Hautala, Kiviniemi, & Tulppo, 2009). Naranjo Orellana, de la Cruz Torres, Sarabia Cachadiña, de Hoyo, and Domínguez Cobo (2015) measured cardiac vagal activity (rMSSD) in Spanish elite soccer players and found lower vagal activity in both supine and standing compared with the present study. Research has suggested that increases in vagal-related HRV indices are generally associated with improved cardiorespiratory fitness (Botek, Krejčí, & Weisser, 2014; Buchheit et al., 2008, 2010; Hautala et al., 2009; Hedelin, Bjerle, & Henriksson-Larsén, 2001) and performance (Atlaoui et al., 2007; Botek et al., 2014; Lamberts & Lambert, 2009; Lamberts, Swart, Capostagno, Noakes, & Lambert, 2010), while decreases are associated with chronic fatigue and/or impaired physical performance (Borresen & Lambert, 2008; Bosquet, Merkari, Arvisais, & Aubert, 2008; Pichot et al., 2000). With regards to sympathovagal balance (Ln LF/HF) in this study, a significantly higher ratio was found in standing for ED compared with EM and CD. In addition, CD demonstrated a significantly lower Ln LF compared with ED and F. GK demonstrated a significantly lower vagal activity compared with F in supine. The increase in vagal activity has been widely accepted to be endurance-related adaptation of ANS in endurance-trained athletes (Aubert et al., 2003). In fact, GK perform during their preparation/matches a lower amount of high intensity endurance exercises compared with other outfield players (Stølen et al., 2005), and therefore, we suggested that this aspect may lead to low vagal activity together with VO_2max level in our GK.

Study limitations

Limitations of the study include the lack of tests that examined other parameters important for soccer performance such as acceleration, speed, agility, repeat-sprint, perceptual and cognitive ability. Also additional HRV measurements are needed to ensure a better indication of true HRV baseline.

Conclusions

To conclude, this study found that different playing positions require specific somatic characteristics, while aerobic capacity and HRV seems to be comparable amongst outfield playing positions. The somatic results are similar to those reported in previous studies performed on professional soccer players. However, aerobic capacity seems to be lower per position in the cohort of players examined, whilst the position differences in various HRV parameters are a novel finding. The results are useful for understanding the somatic and fitness requirements of Czech professional soccer players that can be used for planning training and improving performance.

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Conflict of interest

There were no conflicts of interest.

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