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Original Article

Importance of the functional tests of the professional soccer players in the organization of the training process

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Abstract:
Problem Statement and Purpose: Soccer is a sport characterized by high intensity and duration. The energy needed to play a soccer match is provided by aerobic metabolism. Therefore, it is important to determine such parameters as oxygen consumption and maximal oxygen consumption in soccer players. The aim of the study is to track the changes in the functional indicators of professional soccer players during the spring half-season and to give recommendations for changes in the training plan to increase their performance and reduce fatigue at the end of the season. *Approach*: The study involved 13 professional soccer players and was conducted in the period January – June. Functional examination of respiration – spirometry and determination of gas exchange parameters during exercise – spiroergometry were performed twice at the beginning and at the end of the period.
Results: The spirometry data of the subjects showed values close to the predicted values. The decrease in values at the end of the spring half-season is probably due to the fatigue accumulated during this period. Although the values show a decrease in the parameters, there is no statistically significant difference in the two measurements of the Tifno index, but there is a statistically significant difference in the decrease in VC (Wilcoxon signed rank test, p value = 0.04) and FEO1 (Wilcoxon signed rank test, p value = 0.0002). The fact that even the indicators at the beginning of the study are to some extent underestimated, shows the accumulation of fatigue in the players and the need to rethink the overall training plan with corresponding individual approaches to each soccer player in order to optimize the training-recovery ratio. There was a slight increase (statistically insignificant) in mean VO_2max and VO_2max/kg during the spring half-season, indicating that training resulted in an increase in aerobic capacity. This is an indication that conditioning training is producing the desired result and can be carried out without any major changes. *Conclusions*: The benefit of periodic medical and functional examinations of football players is mainly in two directions. First, it provides information about the current state of health of the athlete under study and his fitness to participate in training and sports competitions. And, secondly, it enables the coach, analyzing the results, to assess the specific functional capabilities of the football players, to make changes in the training schedule and specific exercises, to pay attention to recovery and to apply an individual approach to each specific case in order to improve specific indicators.
Key Words*:* **- spirometry, spiroergometry, Tifno index, vital capacity, FEV1, VO_2max**

Introduction

From a physiological point of view, football is an activity involving each of the energy systems. As several authors have described (Astrand & Rodahl, 1977; Ekblom, 1986; Bangsbo, 1994), football is a sport characterized by short-term actions of high intensity, with breaks of varying duration between them. Heart rate during training as previously was reported (Dzimbova et al., 2019; Radziminski, L, 2021) is indicative for the high intensity training of the professional soccer players. The duration of the match, 90 minutes, implies a large supply of energy from the aerobic system. It is calculated by measuring the heart rate that the energy supply of the aerobic system during a match is between 70% and 80% (Ekblom, 1986; Bangsbo, 1994). In the laboratory, this metabolic pathway is assessed mainly by measuring maximal aerobic power (VO_2max) and the 'anaerobic threshold'. On the other hand, rapid action is explosive and therefore anaerobic strength is also essential.

Although many studies on football have been published in recent years, little has been focused on repetitive measurements in professional football, perhaps because professional footballers are not frequent visitors to the physiological test lab, except for health or contractual reasons at the beginning of the season.
The most commonly used methods for functional testing are stress tests (Niederseer & Löllgen, 2020). They are mainly used to assess endurance and progression during training or after training breaks, e.g. due to illness or to measure the level of fitness during or after rehabilitation. However, they are also used to supplement clinical trials for known or suspected disease in athletes. Exercise testing is mainly conducted with four main purposes (Sarma & Levine, 2006): to assess baseline fitness and prescribe an exercise program or training zones; to assess

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continuous progress after training over a period of time; to diagnose cardiovascular and pulmonary conditions affecting exercise performance; and to induce arrhythmias or assess the hemodynamic response to exercise in an athlete with a known cardiovascular condition to determine whether it is safe to participate professionally in sport.

Spirometry is a standard test for the study of lung function, which has become indispensable for the prevention, diagnosis and assessment of various respiratory disorders. Athletes can be distinguished from members of the general population because they exhibit better cardiovascular function, greater stroke volume, and greater maximal cardiac output. (Astrand & Rodahl, 1977; Ekblom, 1986).

The cardiopulmonary exercise stress test (CPET) is a study of the indicators of the cardiovascular (pulse rate, arterial pressure, ECG) as well as the respiratory system (respiratory rate, respiratory volumes and respiratory gas analysis) during physical exertion. The analysis of these parameters allows to determine the physical capacity and level of training of healthy individuals and athletes (Milani, et al., 2004). Conducting a series of tests on the same individual provides extremely useful information about the effectiveness of training, rehabilitation and therapy programs. On the other hand, measurement of ventilatory anaerobic threshold, respiratory compensation point and heart rate enables the system to automatically calculate training zones for athletes, which are the foundation for building a successful and strictly individualized training program (Avram, et al., 2008). The ventilatory anaerobic threshold does not match the lactate anaerobic threshold.

The aim of the study is to track the changes in the functional indicators of professional soccer players during the spring half-season and to give recommendations for changes in the training plan to increase their performance and reduce fatigue at the end of the season.

Material & methods

Participants

The study involved 13 professional soccer players (age 21.3 ± 4.3 years, height 181.1 ± 4.2 cm and weight 73 ± 3.2 kg). The study was conducted in the period January - June. The participants in the study signed a declaration of informed consent and the permission from the ethics committee to conduct the study was obtained.

Determination of height, weight and BMI

The height measurement was performed with a height meter with an accuracy of 1 cm. The measurement of body weight was performed with a medical scale with an accuracy of 0.1 kg. The body mass index was determined by the formula:

BMI = mass in kg / height^2 in m.

Functional examination of respiration - spirometry

Spirometry was performed with a MasterScreen Diffusion apparatus from E. Jaeger GmbH. From the obtained indicators for the purposes of the study, VC (vital capacity), FEV1 (forced expiratory volume for 1 second) and Tifno index (FEV1 / FVC) were used.

Determination of gas exchange parameters during exercise – spiroergometry

Spiroergometry was performed with a CardiO2 (MedGraphics, Inc) exercise gas exchange monitoring system equipped with a TrackMasterTM treadmill. From the obtained results, the following parameters were used in our work: VO_2max, VO_2max/kg and RER.

The mean maximum running speed achieved in the exercise test and the time to reach the anaerobic threshold were 16.8 km/h and 13.3 min, respectively.

Data analysis

GraphPadPrism (Ver. 3.0) was used for data processing and analysis. Means and standard deviations of all variables were calculated using descriptive statistics. Experimental data are presented in two ways: - as mean values ± SD; and – as individual values for each subject. Statistical software GraphPadPrism was used for statistical analysis of the results (Wilcoxon signed rank test).

Results

Thirteen professional football players participated in the research. Their anthropometric data as well as spirometric and spiroergometric test results are presented in Tables 1 (anthropometric data), Table 2 (spirometry data) and Table 3 (spiroergometry data), respectively.

From the anthropometric data of the soccer players, it is clear that there is very little difference in mean weight and no difference in mean body mass index at the beginning and end of the study. There is no statistically significant difference in these parameters (Wilcoxon signed rank test).

Dicussion

Elite soccer teams are characterized by relative heterogeneity in body size. The overall mean (± SD) values for height and body mass of nine professional teams reported by Reilly & Secher (1990) were 1.77 ± 0.15 m and 74.0 ± 1.6 kg. Tall players have an advantage in certain playing positions and are therefore oriented towards these roles, specifically goalkeepers, central defenders and central forwards. A large range in height is observed in each Danish team (for example, the tallest striker is 1.90 m and the shortest is 1.67 m). This difference can affect the tactical role assigned to individual players. A tall forward can be used as the main player for high balls, while a short forward can be preferred to run for balls played deep into the opposition's defense.

Table 1. Anthropometric data of the study participants.

ID	Age, years	Height, cm	Weight, kg		BMI, kg/m^2	
			1	2	1	2
FP01	18	183	75.7	75.7	22.6	22.6
FP02	20	180	69.5	69.3	21.45	21.5
FP03	19	184	75	76	22.15	22.45
FP04	18	185	66.5	70.4	19.38	20.79
FP05	22	180	77	75.5	23.77	23.3
FP06	18	175	73.4	71.4	23.97	23.31
FP07	19	183	75	72.6	22.4	21.7
FP08	18	190	77.2	79.9	21.39	22.13
FP09	18	186	73.3	73.4	21.19	20.96
FP10	27	177	71	71.2	22.66	22.6
FP11	31	181	73	74.2	22.28	22.65
FP12	27	182	76.9	75.3	23.2	22.6
FP13	23	176	71.2	72.3	23	23.34
Mean	21.4	181.7	73.4	73.6	22.3	22.3
±SD	4.4	4.2	3.2	2.9	1.2	0.8

1 – measurement in January, 2 – measurement in June

Table 2. Data from the spirometric test of the subjects.

Код	VC, l		FEO, l		Tifno index	
	1	2	1	2	1	2
FP01	5.85	5.65	4.72	4.56	81	82
FP02	5.29	5.37	4.95	4.94	94	92
FP03	5.76	5.59	4.67	4.49	79	82
FP04	5.00	5.39	4.4	3.92	88	75
FP05	5.39	5.12	4.29	3.89	80	76
FP06	4.74	4.79	3.46	3.39	73	72
FP07	6.35	5.87	4.86	4.32	77	75
FP08	6.78	6.66	6.15	5.82	91	87
FP09	6.96	6.8	5.99	5.87	86	87
FP10	6.85	6.52	5.49	5.35	80	82
FP11	5.90	5.84	4.29	4.24	73	73
FP12	6.52	6.33	5.58	5.44	86	86
FP13	5.85	5.75	4.63	4.57	79	79
Mean	5.90	5.80	4.9	4.7	82.1	80.6
±SD	0.70	0.60	0.8	0.8	6.5	6.2

1 – measurement in January, 2 – measurement in June, VC – vital capacity, FEO1 – forced expiratory volume per 1 min

Table 3. Data from the spiroergometric test of the subjects.

Код	VO_{2max}, ml/min		VO_{2max}/kg, ml/min/kg		RER	
	1	2	1	2	1	2
FP01	4315	4208	57	55.6	1.13	1.29
FP02	3823	4427	55	63.9	1.11	1.18
FP03	3352	4102	44.7	54	1.15	1.21
FP04	3697	3979	55.6	56.5	1.12	1.16
FP05	4050	4243	52.6	56.1	1.12	1.18
FP06	3956	3478	53.9	48.7	1.15	1.18
FP07	3547	2990	47.3	40.5	1.09	1.24
FP08	4539	4328	58.8	54.2	1.13	1.24
FP09	3738	3945	51.2	53.8	1.07	1.17
FP10	4850	4699	68.3	66	1.19	1.34
FP11	4144	5342	56.8	62.5	1.10	1.20
FP12	3684	3876	47.9	51.5	1.10	1.23
FP13	4181	4526	58.7	62.6	1.21	1.09
Mean	3990.5	4164.8	54.4	55.8	1.10	1.20
±SD	416.9	572.1	6.1	6.9	0.0	0.1

1 – measurement in January, 2 – measurement in June, VO_{2max} – maximum oxygen consumption, RER – respiratory quotient

In the studied group, the average height is much higher (180.7 ± 4.2 cm) than the data published in the literature, with the tallest competitor being 190 cm tall and the shortest 175 cm tall.

The weight of soccer players also varies widely, according to literature data (Reilly, et al., 2000) the average weight is 76.4 ± 7.0 cm. The participants in the study had a lower average body weight of 73.4 ± 4.2 cm, but this is probably due to their younger age (21.4 ± 4.4 years), less experience as professional soccer players and, accordingly, less muscle mass accumulated. Since no body composition measurements were taken, the barer statement is our assumption.

From the anthropometric data of the soccer players, it is clear that there is very little difference in mean weight and no difference in mean body mass index at the beginning and end of the study. There is no statistically significant difference in these parameters (Wilcoxon signed rank test). These metrics are of utmost importance, as a change, especially in a decreasing direction, would be an indicator of excessive workload and insufficient recovery during the spring half-season. Maintaining a constant weight during intense exercise is key in several important ways. First, maintaining optimal muscle mass to support training and performance during soccer matches. And secondly, maintenance of fluid balance, which is of great importance. Rising temperatures this mid-season put questions like timing of training sessions and proper hydration strategy on the agenda. The trainer has successfully tackled both issues and the results are there. Properly structured training process, recovery procedures and adequate diet are the main factors leading to maintaining a constant body weight.

It is generally accepted that elite athletes and physically active individuals tend to have higher levels of cardiorespiratory fitness. It is well known that the musculoskeletal and cardiovascular systems are actively engaged during exercise and that both organ systems undergo adaptive changes in response to regular endurance training. In contrast, it is generally believed that the respiratory system is not significantly different in physically trained individuals compared to a sedentary population (Twisk, et al., 1998). Considering the fact that they are all involved in the transport of oxygen, the exact reason for the significantly lower degree of adaptation during prolonged exercise of the pulmonary system is not fully understood. In the general population, lung volume estimates are based on age, sex, race, and height. The European Respiratory Society/American Thoracic Society (ERS/ATS) reports on lung volume measurements and its reference value for children and adults are widely used, even for athletes (Miller, et al., 2005; Quanjer, et al., 2012). However, there are no normative predictive values for athletes, and general population reference values overestimate lung function in athletes (Dempsey, et al., 2008). Lung development and therefore lung volumes can change performance depending on the type, intensity, severity, duration and frequency of sports activities (Meylan, et al., 2014).

The spirometry data of the subjects showed values close to the predicted values. The average vital capacity and forced expiratory volume for one second were, respectively, at the beginning of the study VC was 103.2 ± 12.5 % and FEO1 was 101.8 ± 14.2 % and at the end – VC was 100.2 ± 9.7 % and FEO1 was 97.2 ± 15.0 %. In the literature (Lazovic, et al., 2015; Degens, et al., 2013) there are data on spirometry in athletes in various sports, and in soccer players they are, respectively: VC – 102.5 ± 13.0 %, FEO1 – 105.2 ± 13.8 % and Tifno index – 100.5 ± 9.3 %. The studied individuals have values of the measured parameters close to those in the literature, and the tendency is for them to slightly decrease at the end of the spring half-season. On the other hand, the studied soccer players were significantly younger (21.4 ± 4.4 years) than the group represented in the research (29.0 ± 4.0 years), and age and duration of physical exertion had an impact on improving spirometric indicators. The decrease in values at the end of the spring half-season is probably due to the fatigue accumulated during this period. Although the values show a decrease in the parameters, there is no statistically significant difference in the two measurements of the Tifno index, but there is a statistically significant difference in the decrease in VC (Wilcoxon signed rank test, p value = 0.04) and FEO1 (Wilcoxon signed rank test, p value = 0.0002).

Although there is a tendency to decrease in both parameters in percentage terms compared to the predicted values, there are statistically significant differences only in FEO1 (Wilcoxon signed rank test, p value = 0.0005), but not in VC. The only correlation found between the values measured in spirometry and anthropometric data was between BMI and the Tifno index (Pearson r = -0.61, p value = 0.03, figure 8), in contrast to the literature (Lazovic, et al., 2015), where correlations were found between these parameters and height and body weight. The fact that even the indicators at the beginning of the study are to some extent underestimated, shows the accumulation of fatigue in the players and the need to rethink the overall training plan with corresponding individual approaches for each soccer player in order to optimize the training-recovery ratio.

Aerobic performance is determined by aerobic power and aerobic capacity. The first component reflects the ability to produce aerobic energy at a high rate and is characterized by maximal oxygen uptake (VO_{2max}). Aerobic capacity refers to the ability to maintain a certain load for an extended period and is synonymous with endurance. Considering that top soccer players run 8-12 km during 90 minutes per match (Bangsbo, et al., 1991; Rhodes, et al., 1986), it is clear that aerobic Stamina is essential for football. Previous studies have found a correlation between VO_2max and distance covered during a match (Helgerud, et al. , 2001). In high-intensity bouts that depend on an anaerobic or lactate energy source, recovery occurs using aerobic metabolism. This requires players to spend significant time at intensities below the anaerobic threshold (Helgerud, et al. , 2001). During a soccer match, sprints are every 90 seconds (Bangsbo, et al., 1991; Thomas & Reilly, 1979). In the context of endurance, each player performs about 1,000 mostly brief activities (Bangsbo, et al., 1991; Davis, et al., 1992; Thomas & Reilly, 1979). In order to recover quickly from such activities, during a soccer match, players must possess a good level of conditioning abilities, mainly VO_2max. Also, the rate of lactate removal depends on lactate concentration, activity in the recovery period, and aerobic capacity. Players with a higher VO_2max may have a lower blood lactate concentration due to enhanced recovery from high-intensity intermittent exercise by: increasing the aerobic response; improved lactate removal and improved phosphocreatine regeneration (Tomlin & Wenger, 2001).

The mean VO_2max of elite soccer players is in the range of 55-67 ml/kg/min (Whitehead, 1975; Helgerud, et al. , 2001; Rhodes, et al., 1986; Thomas & Reilly, 1979). The data obtained for the studied group at the beginning of the study were 54.4 ± 6.1 ml/min/kg, and at the end - 55.8 ± 6.9 ml/min/kg, and in both cases are closer to the lower limit. This shows that the soccer players have not developed their aerobic capacity to the desired level. However, in the study group there are individuals with VO_2max values indicating a high level of aerobic power. Although the table shows a difference between the values of the two measurements, there is no statistically significant difference between them. There was a slight increase (statistically insignificant) in mean VO_2max and VO_2max/kg during the spring half-season, indicating that training resulted in an increase in aerobic capacity. This is an indication that conditioning training is producing the desired result and can be carried out without any major changes. RER values are normal for this type of loading and the higher the value, the more intense the loading was. There was a statistically significant increase in the mean value of RER (Wilcoxon signed rank test, P value = 0.008) at the end of the study. It can be assumed that this is due to the accumulated fatigue after the end of the half-season and, accordingly, the perception of the same load as at the beginning as more intense. No correlation was found between anthropometric data and spirometry measurements, as well as between spirometric parameters and VO_2max, VO_2max/kg and RER.

Conclusions

The organization of the training process takes into account a number of factors: the international sports calendar of the International Football Federation (FIFA) and the European Football Federation (UEFA), football matches at the national level, etc. The correct conduct of training and appropriate recovery aim at improving the sports form of football players and preserving their health.

As a result of the conducted research, the following main conclusions could be drawn: - soccer players have a relatively constant weight during the studied half-season, which shows that their diet is appropriate and provides an opportunity to replenish energy losses and maintain good hydration; - the values of VC, FEO1 and the Tifno index slightly decrease during the study period, which is an indication of accumulated fatigue as a result of the conducted trainings and football matches; - the anaerobic capacity of the studied football players slightly increased during the half-season, which is the result of properly conducted conditioning training; - tracking the results of the athletes' periodic tests gives information about their current condition, but it can also be used to make individual recommendations and changes in training for specific football players in order to improve certain indicators. Analyzing the specific results of each soccer player, the following two main recommendations can be made:

• To pay attention to the time of rest and recovery after training and soccer match, and different procedures can be introduced to improve breathing: yoga, breathing exercises, etc. in order to improve lung functions;

• Carrying out separate training sessions aimed specifically at developing aerobic capacity, which is extremely important for individual soccer players whose gas exchange parameters during exercise are below the average values measured for elite soccer players.

Conflicts of interest - The authors declare no conflicts of interest.

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