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Football Players' "Cardiorespiratory System and Intermittent Endurance" Test

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Abstract

Twenty six football players of the Shandong Luneng youth team (U17), the 2019 season Chinese National Youth Super League champions. Based on a comprehensive assessment of the working capacity and functional support of intermittent endurance, the levels and changes in the reaction of the cardiorespiratory system and energy supply of football players' activities were analyzed under the condition of fatigue cumulating in the process of performing a series of high-speed segments. The prerequisite for testing was the preservation of the parameters of running 70 m in 10 s during the entire testing period. Content of Cardiorespiratory System and Intermittent Endurance test: duration of work in a series – 4 minutes; duration of work with the maximum available intensity – 10 s (running distance 70 m), rest interval – 20 s. The number of combinations of work segments 10 s and rest intervals 20 s in a series is 8. The efficiency of work is assessed by the number of completed series and the reaction of the cardiorespiratory system. The typological differences in the functional support of the special working capacity of football players who had a high level of working capacity were determined. They are associated with a balanced type of aerobic and anaerobic energy supply, with an insignificant tension of the mechanisms for fatigue compensating and a predominantly anaerobic type of energy supply provided a high level of respiratory compensation for metabolic acidosis.

Keywords: *football, U17, intermittent endurance, cardiorespiratory system, aerobic energy supply, anaerobic energy supply*

Introduction

At present, the means and methods of control, assessment and interpretation of its results, which provide information on the functional support of the special working capacity of athletes, acquire a special relevance (McDougal, & Green, 1998; Bompa & Haff, 2009; Iaia & Bangsbo, 2010). Based on the assessment of indicators of the special working capacity of the reaction of the cardiorespiratory system and the energy supply of work, group and individual parameters of special functional training can be developed (Ekblom, 1994; Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002). The implementation of this approach in football is one of the most effective ways to form the organism's functional reserves and their realization in the process of competitive activity (Helgerud, Engen, Wisloff, & Hoff 2001; Iaia et al., 2015). An important condition for the implementation of control as a function of managing the special functional training of football players is the search for means and methods of registration, assessment and interpretation of the control results in accordance with the structure of the functional support of special working capacity(Przybylsky & Mischenko, 2005; Impellizzeri et al., 2008). In accordance with this, quantitative and qualitative characteristics, reflecting the integral manifestations of functional readiness, acquire importance. Football related special literature covers the characteristics of the functional support of special working capacity under conditions of a

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pronounced repeated and variable nature of competitive load with the development of fatigue, under the general concept of intermittent endurance (Przybylsky, 2003; Gutierrez Diaz Del Campo, Pastor Vicedo, Gonzalez Villora, & Contreras Jordan, 2010).

The data presented in the modern literature characterizes the functional support of football players' special working capacity in the conditions of intense motor activity of variable character (Hoff & Helgerud, 2004; Reilly, 2000).

At the same time, the suggested means and methods for assessing the working capacity and functional capabilities of football players do not allow to fully assess one of the most important aspects of the functional readiness of football players – the ability to perform work in conditions of maximum intensity at short runs during the development of fatigue. We are talking about the choice of a test task that allows standardizing the measurement conditions and simulating the load at which a football player reaches the highest effort of the functional support of special working capacity, typical for periods of intense game activity. An important aspect of the assessment is the analysis of the reaction of the cardiorespiratory system and energy supply of work to the development of hypoxia. hypercapnia, products of anaerobic metabolism(Warren, 1987; Miyamoto, Nakazono, & Yamakoshi, 2007; Puype, 2013). This will make it possible to determine the individual characteristics of the reactivity of the cardiorespiratory system and the energy supply of the work of football players, including the possibility of compensating for fatigue in the process of modelling the intense motor activity of football players (Mischenko, Lysenko, & Vinogradov, 2007; Przybylsky & Mischenko, 2005).

The aim of the study is the development and experimental verification of a test aimed at intermittent endurance, the reaction of the cardiorespiratory system and energy supply of work as an assessment of the functional support of the special working capacity of football players.

Methods

Subjects

Twenty six (26) football players of the Shandong Luneng youth team (U17), of 16-17 years old, champions of the 2019 Chinese National Youth Super League (U17).

All participants were informed of the requirements prior to the study, and their parents and coaches gave their informed written consent for them to participate. The local research ethics committee in the spirit of the Declaration of Helsinki approved all procedures (The protocol of National University of Ukraine on Physical Education and Sport No 2 of December, 16, 2020).

Design

Research protocol

Oxygen consumption (VO_2), CO_2 production (VCO_2), minute ventilation (V_E), was assessed on a breath-by-breath basis using an Oxycon mobile (Jaeger) metabolimeter. The blood lactate concentration was assessed using a portable lactate analyzer (Biosen S. line lab +) on a blood sample obtained from the ear lobe at the end of the last test series at third and fifth minute of recovery.

CRS & IE test Protocol

The nominal name of the Cardiorespiratory system and intermittent endurance test is CRS & IE test. The work parameters modelled the conditions for the realization of the power and capacity of anaerobic energy supply (La), a high degree of mobilization of the reaction of respiratory compensation of metabolic acidosis (V_E/VCO_2) and aerobic energy supply of work (VO_2). Duration of work in a series – 4 minutes; run length – 70 m, run timing – 10 s, rest interval – 20 s. The number of combinations of 10 s work segments and 20 s rest intervals in a series was 8. The number of series was regulated by "failure" or the inability to maintain the specified running parameters (work intensity). Series that have been completed in full were registered. The duration of the recovery period between series was two minutes. After series 3 and 4, the duration of the rest intervals could be increased to 3–5 minutes, depending on the recovery of the heart rate up to 120 beats / min. The testing scheme is shown in Figure 1.

The working capacity was assessed by the number of work performed (the number of series). If one or two series were completed – 1 point, three or four series – 3 points, five

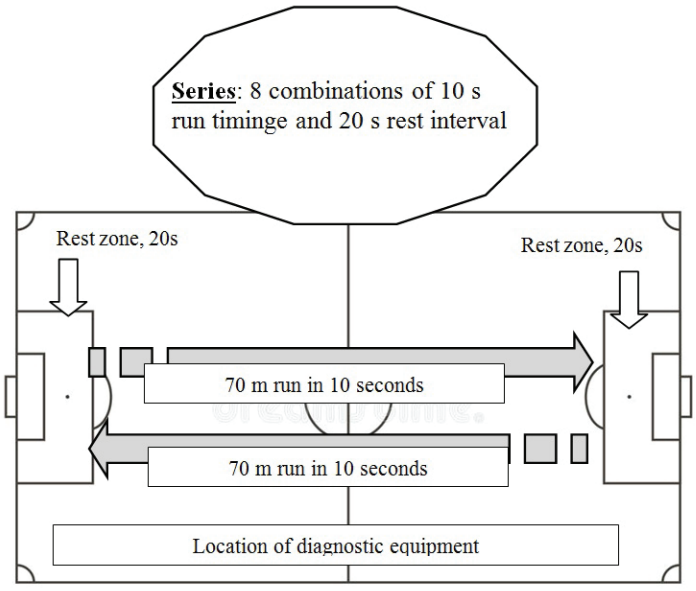

FIGURE 1. CRS & IE testing scheme

or more series – 5 points.

The indicators of the reaction of the cardiorespiratory system and the energy supply of work are considered as criteria for the effectiveness of the functional support of football players' special working capacity. The indicators of consumption of O2 (VO2), blood lactate, specific indicators of pulmonary ventilation and CO_2 emission were analyzed. All indicators were recorded during the first and third series. The highest average values of indicators for 10 s of work on a segment in a series were taken as a basis. Blood sampling for measuring the concentration of blood lactate was carried out at 3 and 5 minutes of the recovery period after the last series. The highest rate was registered.

Statistical Analysis

The statistical analysis is using the Statistical Package for the Social Sciences (SPSS 25.0). The methods of the mathematical statistics used were descriptive statistics, selective method. The Shapiro Wilk test was used in testing for normality. As data was not normally distributed, Mann-Whitney test (U) was used to determine the statistical significance of the differences between two independent samples and Wilcoxon test (T) for comparing two dependent samples. A significance level (that is, the probability of error) was assumed to be p=0.05. The informativeness of the tests and indicators was recorded, evaluated under the standard conditions of measurement.

Results

The indicators of a homogeneous group of football players (n=26), recorded in the process of performing the first and third series of segments (indicators of the reaction of cardiorespiratory system and aerobic energy supply) and indicators of the concentration of blood lactate are presented in Table 1.

The analysis of the average indicators (Table 1) indicates a clear tendency to an increase in the indicators of the power

Table 1. The indicators of changes in the functional capabilities of football players during the CRS & IE test (n=26)

Parameter*	The interval of data recording					
	First series		Third series		After the test	
	$\overline{x}$	SD	$\overline{x}$	SD	$\overline{x}$	SD
VO_2, ml·min^{-1}·kg^{-1}	37.3	2.3	48.8**	3.7	–	–
			T=23, p=0.000469			
V_E/VCO_2 ,conventional units	37.1	2.1	39.4	2.7	–	–
			T=146, p=0.657069			
La, mmol·l^{-1}	–	–	–	–	13.1	1.9

Legend: * – average values of the indicator during overcoming run in 10 second: ** – the differences in football player's indicators between the first and third series are significant at p<0.05

of the cardiorespiratory system and the energy supply of football player's work. The individual differences in the indicators (CV) of the reaction of cardiorespiratory system and the energy supply of work, which increase in the process of performing the third series, draw attention. Wilcoxon signed-rank test (T) was used to compare two repeated measurements on a sample of 26 football players' indicators between the first and third series. Differences in the indicators of the first and third series, respectively: consumption of O_2 – 6.2% and 7.6%, V_E/VCO_2 – 5.7% and 6.9%; differences in blood lactate concentration – 14.5%. These differences characterize high and lowered indicators of cardiorespiratory system reaction and energy supply in a homogeneous group of athletes.

The analysis of football player's working capacity showed a high level of differences in intermittent endurance. The average working capacity indicators were 3.5±1.2 points; 34.2% ($\overline{x}$ ±SD; CV). Two groups of athletes are clearly distinguished, conventionally named Group "A" and Group "B". The first Group "A" – nine footballers completed 5 or more series; the second Group "B" – fifteen players completed 3–4 series. Two football players showed negative test results – less than three episodes.

Those results provided the basis for assessing the typological differences in the reaction of cardiorespiratory system and the energy supply of work in football players with high and low levels of intermittent endurance. For this, an analysis of the typological differences in the reaction of cardiorespiratory system and the energy supply of football player's work of the Groups "A" and "B" was carried out. Table 2 presents the analysis results of indicators of the cardiorespiratory system reaction and energy supply of football player's work of the Groups "A" and "B". The Mann-Whitney test (U) was used to determine the differences between indicators of the Groups "A" and "B".

As shown in Table 2, football players with a high level of intermittent endurance in the first segment had a higher level of aerobic energy supply response. This tendency remained in the process of performing the third series. Differences between the reaction of the cardiorespiratory system and the energy supply of work were noted during the third segment of the testing program. This kind of tendency was noted when analysing changes in cardiorespiratory system response (V_E/VCO_2).

Particular attention was drawn to the results of a comparative analysis of the respiratory response to CO_2 emission recorded in the first and third series. According to the special literature, changes in the reaction of cardiorespiratory system show the possibilities of respiratory compensation for metabolic acidosis (Mischenko et al., 2007). This is one of the components of the reaction to compensate for fatigue in the process of intensive physical activity (Mischenko & Monogarov, 1995). In football players with a high level of intermittent endurance (Group "A"), the reaction of respiratory compensation of metabolic acidosis increased by 5.4%, in football players in Group "B" – by 2.4%.

Analysis of the reaction of anaerobic energy supply (according to La) showed a higher level of indicators of blood lactate concentration after the test task in the football players

Table 2. Individual indicators of the reaction of the cardiorespiratory system and energy supply of football player's work during the CRS & IE test

Parameter	The interval of data recording								
	First series			Third series			After the test		
Indicators of Group "A" football players who scored 5 points (n=9)									
Statistics	$\overline{x}$	25%	75%	$\overline{x}$	25%	75%	$\overline{x}$	25%	75%
VO_2, ml·min^{-1}·kg^{-1}	38.3	37.1	39.5	49.8**	47.9	51.9	–	–	–
V_E/VCO_2,conventional units	37.1	36.0	39.1	39.2**	37.5	41.7	–	–	–
La, mmol·l^{-1}	–	–		–	–		14.1	12.4	15.8
Indicators of Group "B" football players who scored 3 points (n=15)									
Statistics	$\overline{x}$	25%	75%	$\overline{x}$	25%	75%	$\overline{x}$	25%	75%
VO_2, ml·min^{-1}·kg^{-1}	35.5	33.5	37.1	45.8**	43.9	48.1	–	–	–
V_E/VCO_2,conventional units	36.1	35.0	38.1	37.0**	36.4	38.5	–	–	–
La, mmol·l^{-1}	–	–		–	–		12.1	11.0	13.2
Mann-Whitney test	U=61, p=0.698			U=21, p=0.0056			U=39.5, p=0.095		

Legend: * – average values of the indicator in the process of overcoming run in 10 second; ** – differences in indicators between Group "A" and "B" are significant at p<0.05

of Group "A". At the same time, in this group of football players, blood lactate concentration indices have a higher level of individual differences. This gives reason to think about the differences in the structure of the football players' energy supply. The characteristics of individual differences are provided by the analysis of individual indicators of the players of Group "A".

With a general tendency towards the balance of aerobic and anaerobic reactions, two athletes showed the type of individual reaction of cardiorespiratory system and energy supply of work. This type is characterized by high anaerobic capacity and metabolic acidosis compensation response. Two sportsmen of Group "A" are marked with typological characteristics of endurance, which is based mainly on anaerobic sources of energy supply, provided that the reaction of respiratory compensation of metabolic acidosis is activated. In these athletes, the level of O_2 consumption in the third series was at the level of 47.9 and 47.3 VO_2, ml·min^{-1}·kg^{-1}, the concentration of blood lactate was 15.8 and 16.1 mmol·l^{-1}, the increase in V_E/VCO_2 was 6.2 and 6.9 conventional units.

The test results showed high rates of cardiorespiratory system reaction and energy supply of work. High individual differences in indicators are noted. The typological features of the reaction of cardiorespiratory system and energy supply in athletes with high and decreased levels of working capacity are given. This testifies to the informativeness of the given quantitative and qualitative indicators of the reaction of cardiorespiratory system and energy supply of work, as well as the characteristics of the working capacity of football players, which show the level of intermittent endurance.

Discussion

In the specialized literature on football, the conditions for monitoring, evaluating and interpreting indicators of special working capacity and functional capabilities of football players of different ages and qualifications are presented (Pereira, 2002; Beswick, 2010, Longo, Aquilino, Cardey, & Lentini, 2016). Special tests "Yo-Yo", "Bangsbo", "Hoff-Helgerud" and others have become widespread in practice due to their informative value and the possibility of using them in natural conditions of sports training (Bangsbo, 1999: Hoff & Helgerud, 2004; Bangsbo, Iaia, & Krustrup, 2008). The possibilities of registering the reaction of cardiorespiratory system and anaerobic energy supply, as well as indicators of working capacity of football players in natural working conditions are shown (Krustrup et al., 2006; Iaia & Bangsbo, 2010; Bujnovky, 2019).

The test results provided a lot of important information about the structure of functional support for the special working capacity of football players, their typological and individual characteristics. This made it possible to increase the special orientation of functional training, to develop and use modes of training work in accordance with the body's response to the load. The accumulated scientific and empirical knowledge made it possible to expand the understanding of the possibility of obtaining information about the functional readiness of football players, taking into account highly specific manifestations of functional capabilities. At the same time, there was an understanding that the reserves of the special working capacity of football players are based on the search for new opportunities for the development of functional capabilities in extreme conditions of playing activity. This is largely due to the development and implementation of functional support of high-speed modes of training and competitive work in the process of mobilizing the reaction to compensate for fatigue.

When developing the test task, we took into account the fact that during the load of maximum and submaximal intensity, the athlete reacts to the development of hypoxia. hypercapnia, accumulation of products of anaerobic metabolism. In the opinion in athletes with a high level of preparedness, these states are physiological stimuli (drives) of the reaction, which have additional effects on the mobilization and implementation of functions in the process of intense physical load. According to the authors Miyamoto, Nakazono and Yamakoshi (1987); Mischenko and Monogarov (1995); Mischenko et al. (2007); Ward, Lamarra and Whipp (1996), the ability of an athlete's organism to quickly, adequately and fully respond to physical activity, which is accompanied by neurohumoral stimuli of the reaction stimulates the kinetics of cardiorespiratory system and energy supply of work. This stimulates the achievement of peak characteristics of the reaction of cardiorespiratory system and energy supply of work, affects the increase in the

reaction of respiratory compensation for metabolic acidosis.

The reactivity of the cardiorespiratory system and the power supply of work to repeated loads of maximum intensity is the main target setting for the implementation of the testing program. This kind of information will help to clarify the athlete's ability to respond to training and competition loads.

For this, testing regimes were developed, which simulated the conditions for mobilizing the reaction of cardiorespiratory system and energy reserves of the body during repeated performance of the high-speed work modes. The accumulation of fatigue occurred as a result of the cumulation effects of running 70 m segments in 10 s. The combination of work and rest modes, load for 10 s and rest for 20 s stimulated the consumption of O2 and the reaction of respiratory compensation of metabolic acidosis in response to the development of hypoxia, hypercapnia, and the accumulation of products of anaerobic metabolism. This made it possible to realize the reserves of the functional support of special working capacity under the conditions of high-speed modes of operation, to form a reaction structure that characterized the specific manifestations of the special endurance of football players, or intermittent endurance, as indicated in the special literature on football. To assess the specific manifestations of intermittent endurance when performing a series of segments of high-speed work, the test conditions were formulated. which received the code name Cardiorespiratory System and Intermittent Endurance test – CRS & IE test.

As a result of the CRS & IE test, the typological characteristics of the reaction were determined for football players, who had a high and reduced level of special working capacity. A high level of football player's working capacity provides two types of reaction of cardiorespiratory system and energy supply of work. The first type is characterized by a balanced manifestation of aerobic and anaerobic energy supply, a moderate stress reaction of cardiorespiratory system at the end of work. The second type is characterized by an increased level of anaerobic metabolism and a high level of the reaction of respiratory compensation for metabolic acidosis.

As a result of the study, a program for testing football players was developed and experimentally tested. The program is based on a series of short accelerations that, when repeated, stimulate fatigue. As a result, new possibilities for monitoring and evaluating the functional support of the football player's special working capacity are shown. The presented program makes it possible to determine the level of functional readiness, typological features of the functional support of the player's working capacity, the focus of special functional training and individual parameters of training work during the period of fatigue compensation in the process of developing the speed capabilities of football players.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

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References

Bangsbo, J. (1999). *Physical Fitness of Soccer Players*. Warszawa.

Bangsbo, J., Iaia, F. M., & Krustrup, P. (2008). The YoYo intermittent recovery test. *Sports Med., 38*. 37–51.

Beswick, B. (2010). *Focused for soccer*. 2nd ed. United States. Human Kinetics.

Bompa, T. O., & Haff, G. G. (2009). *Periodization: theory and methodology of training (5th ed.)*. Champaing: Human Kinetics.

Bujnovky, D., Maly, T., Ford, K. R., Sugimoto, D., Kunzmann, E., Hank, M. & Zahalka, F. (2019). Physical Fitness Characteristics of Highlevel Youth Football Players: Influence of Playing Position. *Sports, 7*(2), 46.

Gutierrez Diaz Del Campo, D., Pastor Vicedo, J. C., Gonzalez Villora, S., & Contreras Jordan, O. R. (2010). The relative age effect in youth soccer players from Spain. *Journal of sports science & medicine*, *9*(2), 190–198.

Ekblom, B. (1994). *Handbook of Sport Medicine and Science*. Football (Soccer). London – Boston: Blackwell Science Publishers.

Helgerud, J., Engen, L. C., Wisloff, U., & Hoff, J. (2001). Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc., 33,* 1925–1931.

Hoff, J., & Helgerud, J. (*2004*). Endurance and strength training for soccer players: physiological considerations.*Sports Medicine, 34*(3), 165–180.

Hoff, J., Wisløff, U., Engen, L. C., Kemi, O. J., & Helgerud, J. (2002). Soccer specific aerobic endurance training. *British journal of sports medicine*, *36*(3), 218–221. https://doi.org/10.1136/bjsm.36.3.218

Iaia, F. M., Fiorenza, M., Perri, E., Alberti, G., Millet, G. P., & Bangsbo, J. (2015). The Effect of Two Speed Endurance Training Regimes on Performance of Soccer Players. *PLoS One, 10*(9).

Iaia, F. M., & Bangsbo, J. (2010). Speed endurance training is a powerful stimulus for physiological adaptations and performance improvements of athletes. *Scand J Med Sci Sports, 20*(Suppl 2), 11–23.

Impellizzeri, F., Rampinini, E., Castagna, C., Bishop, D., Bravo, D. F., Tibaudi, A., & Wisloff, U. (2008).Validity of a repeated sprint test for football. *Int. J. Sports Med., 29,* 899–905.

Krustrup, P., Mohr, M., Nybo, L., Jensen, J. M., Nielsen, J. J., & Bangsbo, J. (2006). The Yo–Yo IR2 test: physiological response, reliability, and application to elite soccer. *Med Sci Sports Exerc. 38*(9), 1666–1673.

Longo, A. F., Aquilino, G. D., Cardey, M. L., & Lentini, N. A. (2016). VO_2max assessment in athletes: A thorough method comparison study between Yo-Yo test and direct measurement (Internet page). Available online 15 September 2016. https://www.apunts.org/en-vo-2max-assessment-in-athletes-articulo-X1886658117608472

McDougal, D., & Green, G. (1998). *Physiological testing of high-class athletes: scientific and practical guidance*. Kyiv: Olympic Literature.

Mischenko, V., & Monogarov, V. (1995). *Phisiology del deportista.* Editorial Paidotribo.

Mischenko, V. S., Lysenko, E. N., & Vinogradov, V. E. (2007). *Reactive properties of the cardiorespiratory system as a reflection of adaptation to intense physical training in sports: monograph*. Kiev. Naukoviysvit.

Miyamoto, Y., Nakazono, Y., & Yamakoshi, K. (1987).Neurogenic factors affecting ventilatory and circulatory responses to static and dynamic exercise in man. *Japanese Journal Physiol., 37*(3), 435–446.

Pereira, J. (2002). Fitness Testing and Control of the Training Process in Soccer. *7th Congress of Sport Science (3536).* Athens.

Przybylsky, V. (2003). Special physical fitness of qualified football players in the preparatory period of training. *Science in Olympic Sports, 1,* 23-27.

Przybylsky, V., & Mischenko, B. (2005). *Functional readiness of highly qualified football players*. Kiev, Naukoviysvit.

Puype, J., Van Proeyen, K., Raymackers, J. M., Deldicque, L., & Hespel, P. (2013). Sprint interval training in hypoxia stimulates glycolytic enzyme activity. *Med Sci Sports Exerc., 45*(11), 2166–74.

Reilly, T. (2000). *The physiological demands of soccer*. Copenhagen: Institute of Exercise and Sport Sciences, University of Copenhagen.

Ward, S. A., Lamarra, N., & Whipp, B. (1996). The control components of oxygen uptake kinetics during high intensity exercise in humans. *Book of Abstract (268–269)*.

Warren, R. L. (1987). Oxygen uptake kinetics and lactate concentration during exercise in humans. *Am. Rev. Respir. Disease., 135*(5), 1080–1084.