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, Wisloff, 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
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 reactivity of the cardiorespiratory system and the 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 (VO₂), CO₂ production (VCO₂), minute ventilation (Vₑ), 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 (Vₑ/VCO₂) and aerobic energy supply of work (VO₂). 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
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 CO2 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 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 \( \text{O}_2 \) – 6.2% and 7.6%, \( V_{E}/V_{CO2} \) – 5.7% and 6.9%; differences in blood lactate concentration – 14.5%. These differences characterize high and lowered indicators of intermittent endurance. The average working capacity indicators were 3.5±1.2 points; 34.2% (Group “A”), the reaction of respiratory compensation of metabolic acidosis (Mischenko et al., 2007). This is one of the components of the reaction to compensate for fatigue 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 trend was noted when analysing changes in cardiorespiratory system response (\( V_{E}/V_{CO2} \)).

Particular attention was drawn to the results of a comparative analysis of the respiratory response to CO2 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 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 trend was noted when analysing changes in cardiorespiratory system response (\( V_{E}/V_{CO2} \)).

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 trend 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 trend was noted when analysing changes in cardiorespiratory system response (\( V_{E}/V_{CO2} \)).

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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.
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 O2 consumption in the third series was at the level of 47.9 and 47.3 ml·min⁻¹·kg⁻¹, the concentration of blood lactate was 15.8 and 16.1 mmol·l⁻¹, the increase in V̇̇O2/VE 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", "Hof-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, & Krstrup, 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 (Krstrup et al., 2006; Iaia & Bangsbo, 2010; Bujnovsky, 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 of 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); 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>The interval of data recording</th>
<th>Indicators of Group &quot;A&quot; football players who scored 5 points (n=9)</th>
<th>Indicators of Group &quot;B&quot; football players who scored 3 points (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistics</td>
<td>First series</td>
<td>Third series</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>VO2, ml·min⁻¹·kg⁻¹</td>
<td>38.3</td>
<td>37.1</td>
<td>39.5</td>
</tr>
<tr>
<td>V̇̇O2/VE,conventional units</td>
<td>37.1</td>
<td>36.0</td>
<td>39.1</td>
</tr>
<tr>
<td>La, mmol·l⁻¹</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mann-Whitney test</td>
<td>U=61, p=0.698</td>
<td>U=21, p=0.0056</td>
<td>U=39.5, p=0.095</td>
</tr>
</tbody>
</table>

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