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Original Article

Adaptation of the cardioresphiratory system to hypoxic actions of the rugby players depending on the playing position

ANATOLY ROVNIY[1], VLADLENA PASKO[2], ARTUR MARTYROSYAN[3]
[1]Department of hygiene and physiology of a man, Kharkiv state academy of physical culture, UKRAINE
[2]Department of Computer Science and Biomechanics, Kharkiv state academy of physical culture, UKRAINE
[3]Department of Sports Games, National University of Physical Education and Sport of Ukraine, UKRAINE

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Abstract:

Purpose: to study the regularities of the adaptive mechanisms of the organism of rugby players to normobaric hypoxic influence at the stage of specialized basic training. Results: 10 hypoxic sessions were performed during recurrent respiration into closed space, each of which included 10 episodes. Interval hypoxic training was carried out on the fixing basis of the organism reaction to a gradual decrease in the volume of oxygen (O_2) in the respiratory air. During recurrent respiration, the cardiovascular system (blood pressure, systolic and diastolic, heart rate) and respiratory system (pulmonary ventilation, respiration rate, O_2 utilization rate, percentage of CO_2 accumulation and percentage of O_2 in the exhaled air were recorded in the closed space. Regression analysis has made it possible to determine the main factors for ensuring the duration of recurrent respiration. Research materials indicate hypoxic training, as the increase in adaptability to hypoxia is the mechanism for the development of the special working capacity of rugby players during sports activities. Conclusions: the results of the study deepen information about the features of adaptation mechanisms to certain competitive activities. The inclusion of interval hypoxic training in the training contributed to greater increase in the anaerobic performance of rugby players.

Key words: adaptation, Rugby League, recurrent respiration, hypoxia.

Introduction

One of the most important problems in the training of athletes is the management of training and competitive activities. The level of sports training is formed due to the development of the functional capabilities of the athlete's organism, which is carried out through physical, technical-tactical, psychological and integral training activities. The conditional separation of the training process into relatively independent parties makes it possible to regulate awareness of its structural state, as well as to systematize methods and means, and thus develop a system for monitoring and managing the training process [12, 13,19, 21, 25].

Rugby League is one of the rugby varieties, which combines the complexity of the technical elements of the game with a high intensity of motor activities in the face of opposition rivals. Rugby League requires targeted sports training, the basis of the structure is physical, technical, tactical, psychological and theoretical training, which exist in a dynamic relationship [14, 16].

Modern Rugby League club places high demands on the level of motor qualities and functional capabilities of the athlete. The motor activity of a rugby players is very diverse and complex. It is characterized by great variability of the applied movements of different in character and structure, complexity of individual, group and team actions, continuous change of situations, dynamic and static operation of variable power. All this requires comprehensive, well-planned and purposeful training, development of physical qualities of rugby players – strength, speed, endurance, coordination abilities, flexibility [15, 21].

Motor continuous activity on the field lasts 70-90 seconds of intensive speed-force activity, which is provided by anaerobic productivity. Therefore, during the exercise of speed-strength exercises, exercise should occur with maximum intensity, which contributes to anaerobic motor activity [30].

An important role in the process of long-term improvement of athletes is played by the stage of specialized basic training. Increasing the level of the functional capabilities of the body is the main task of this stage. Further development of physical qualities and improvement of technical preparedness is built in accordance with the playing role [17, 25, 28]. Physical training at this stage is built with the predominance in the development of high-speed and speed-strength qualities, special and speed-strength endurance for creating the high level of overall functional readiness [1, 19]. Individual effects of training loads are taking into account the morphofunctional features and playing role of rugby players [8, 20]. In practice, the means are widely used to increase the functional potential of the athlete's organism without using a large amount of work. At this stage, it is necessary to carefully apply large amounts of physical activity aimed at increasing aerobic capacity [4, 14].

Corresponding Author VLADLENA PASKO, E-mail: vladlenap05@gmail.com

Often, practice coaches plan to perform large amounts of training loads with relatively low intensity, explaining this by the need to create the strong aerobic base, on the basis of which the athlete will have improved performance and recovery process. However, it must be taken into account that athletes who are prone to morphological or functional features for speed-power and complex co-ordination work inherent in Rugby League, significant aerobic loads can dramatically inhibit the development of these opportunities [13, 20]. Such training often becomes an obstacle of the growth of their skill, because – there is a restructuring of the muscular tissue, which increases the ability to work for endurance and at the same time, the ability to manifest the speed-strength qualities is suppressed. Therefore, planning for functional training at this stage should be tailored to the individual abilities and the game specialization of the athlete.

The lack of objective data on the technology of hypoxic training of rugby players and determined the direction of our studies.

Materials and methods

Participants. 30 sportsmen (14 attackers and 16 defenders) aged 16-18 from the Pokrovsk Youth Sports School (Donetsk region) took part in the research. They had the level of training of the first sports category and the candidate for master of sports in Rugby League.

The research design of the study was intended to establish a special effect on the organism of rugby players in normobaric interval hypoxic training. For this purpose, a 10-day course of 10 sessions per day was applied by the method of return breathing into a Douglas bag with a volume of 30 liters.

Statistical analysis

Generalization of the studied characteristics was assessed by mean arithmetic value, standard deviation and error of mean arithmetic. Confidence of differences between mean values was stated by Student's t-criterion. Assessment of statistical hypothesizes based on 5% significance level. For statistical processing of data we used licensed program Microsoft Excel (2010). Statistical analysis of the received results was conducted, considering recommendations on Microsoft Excel tables' usage for computer data analysis.

To establish the mechanisms of adaptation to hypoxic conditions, regression analysis was used, which determines the role of each factor in hypoxic performance. To establish the most important factors in providing adaptation to hypoxic conditions, a stepwise regression regression method was used.

Results

The initial materials of the study (table 1) indicate a gradual decrease in the duration of recurrent respiration in each series and a significant correlation between the stresses of carbon dioxide ($FeCO_2$) and oxygen (FeO_2). Thus, the duration of recurrent respiration at the beginning of the first session in the tenth series decreased by 98,57% for attackers and 92% for defenders. This was facilitated by the increase in $FeCO_2$ by 82,5% for attackers and by 82,7% for defenders. It is characteristic that the tension of FeO_2 after the tenth series occurs to a greater extent of the attackers (by 39,4%) against the defenders (by 33,3%). Estimating the dynamics of the state of oxygen transport system parameters, it is established that the heart rate significantly increases in order to accelerate the oxygen delivery process: for attackers by 43,6%, and for defenders by 40,9% ($p <0.02$).

Table 1. Indicators of the reaction of the oxygen transport system of rugby players at the beginning of hypoxic training (n = 30)

T, min.	Role	$FeCO_2$, %	FO_2, %	Respiration volume litre per min.	Heart beats per min.	Coefficient O_2, мl/per min.
7,0±0,01	attackers	2,2±0,03	18,2±0,03	8,8±0,07	66,2±0,7	35,4±0,7
7,5±0,03	defenders	1,8±0,01	19,3±0,07	9,4±0,01	65,5±0,4	32,1±1,4
6,4±0,01	attackers	4,3±0,02	15,7±0,03	9,14±0,05	69,4±0,9	34,3±1,2
6,8±0,03	defenders	4,0±0,02	17,0±0,06	10,6±0,01	71,4±0,7	33,4±0,9
5,2±0,01	attackers	5,7±0,03	14,2±0,02	11,5±0,03	73,3±1,03	34,8±0,7
5,8±0,04	defenders	5,4±0,03	15,5±0,07	12,3±0,02	72,2±0,9	36,1±0,9
3,9±0,04	attackers	6,7±0,02	13,4±0,03	11,3±0,04	76,8±1,01	33,6±0,6
4,4±0,03	defenders	6,1±0,01	14,3±0,02	12,1±0,01	75,3±1,01	31,3±0,4
3,0±0,04	attackers	7,3±0,03	12,8±0,05	11,0±0,05	82,2±1,03	32,8±0,2
3,4±0,02	defenders	6,4±0,03	14,0±0,04	11,9±0,04	84,2±1,01	29,7±1,1
1,8±0,01	attackers	6,9±0,04	12,5±0,06	11,2±0,05	87,3±1,03	31,2±1,12
2,2±0,004	defenders	6,8±0,02	13,8±0,01	12,0±0,02	96,4±1,1	30,5±0,7
1,2±0,03	attackers	7,5±0,03	12,1±0,04	11,4±0,01	91,5±0,9	30,5±0,9
1,6±0,02	defenders	7,2±0,03	13,2±0,08	12,3±0,07	105,6±0,9	32,7±0,9
0,8±0,01	attackers	7,9±0,04	11,8±0,04	11,7±0,05	107,4±1,07	28,6±0,12
1,2±0,03	defenders	7,4±0,03	12,6±0,03	12,8±0,01	109,9±1,01	26,5±0,7
0,7±0,01	attackers	8,4±0,03	11,6±0,07	11,9±0,03	112,5±1,02	27,6±1,1
0,8±0,01	defenders	7,6±0,03	12,2±0,04	13,6±0,06	111,3±1,02	26,0±1,1
0,6±0,03	attackers	8,8±0,03	11,3±0,01	12,3±0,04	119,4±0,91	26,9±0,8
0,6±0,03	defenders	7,8±0,04	11,8±0,06	14,2±0,03	114,2±1,3	27,3±1,2

Analyzing the materials of the study it is evident that at the beginning of the experiment there is the constant increase of $FeCO_2$ in the exhaled air, that is a stimulator for increasing pulmonary ventilation. It is worth noting that the increase in heart rate occurs in parallel with pulmonary ventilation and was 43,6% for attackers and 40,4% for defenders.

It is also established that the change in the parameters of the oxygen transport system takes place to a greater extent of the attackers. In our opinion, the defenders activity during the game is many times greater than the impact of hypoxic effects, they perform a much larger volume of motor actions with a lack of oxygen, which increases their hypoglycasemic.

The results of the studies indicate that the compensatory mechanism during recurrent respiration in closed space is an increase in pulmonary ventilation (respiration volume litre) and heart rate.

Normobaric interval hypoxic training of rugby players lasted 10 sessions, at the end of each mesocycle. Each session consisted of 10 series.

Table 2 presents the materials of the study of the tenth session of the preparatory mesocycle, which indicate a significant increase in the duration of each series of recurrent respiration and an increase of the levels of the functional state of the cardiorespiratory system.

Table 2. Indicators of reaction of the oxygen transport system of rugby players after sessions of hypoxic training (n = 30)

T, min.	Role	$FeCO_2$, %	FO_2, %	Respiration volume litre per min.	Heart beats per min.	Coefficient O_2, мl/per min.
7,4±0,03	attackers	1,8±0,01	18,1±0,04	9,1±0,1	67,4±0,7	36,2±0,6
8,5±0,03	defenders	2,2±0,02	18,2±0,06	10,36±0,02	64,4±0,6	39,2±0,4
7,2±0,03	attackers	4,4±0,1	17,0±0,1	9,9±0,11	69,6±0,9	35,2±1,1
7,4±0,04	defenders	3,4±0,03	18,4±0,1	11,85±0,12	68,6±1,01	38,3±0,3
6,0±0,07	attackers	4,9±0,04	16,2±0,03	10,8±0,09	71,5±0,7	35,1±0,9
6,8±0,07	defenders	3,8±0,07	16,9±0,04	12,3±0,7	70,8±0,4	36,4±0,7
5,4±0,01	attackers	5,4±0,06	14,8±0,02	11,5±0,6	76,8±0,9	34,6±0,8
5,9±0,03	defenders	4,4±0,03	15,5±0,05	12,8±0,17	72,2±0,7	35,8±0,6
3,8±0,04	attackers	6,2±0,01	14,0±0,11	12,0±0,06	82,3±1,03	31,3±0,5
4,5±0,04	defenders	5,1±0,07	14,3±0,02	12,5±0,03	76,6±0,9	33,3±0,9
2,9±0,07	attackers	6,8±0,03	13,6±0,12	12,4±0,07	87,3±1,1	29,6±0,7
3,2±0,05	defenders	5,9±0,01	14,0±0,05	12,6±0,04	80,5±1,12	30,7±0,9
2,0±0,06	attackers	7,4±0,03	13,0±0,07	12,8±0,1	90,8±0,9	27,6±0,4
2,6±0,04	defenders	6,6±0,04	13,8±0,07	13,2±0,03	87,3±0,8	28,9±0,1
1,6±0,03	attackers	7,8±0,03	12,8±0,06	12,4±0,02	93,3±0,9	26,6±0,9
1,8±0,07	defenders	7,1±0,02	13,2±0,04	13,6±0,1	90,1±0,6	28,4±0,9
1,6±0,05	attackers	8,2±0,03	12,5±0,02	12,8±0,07	105,6±0,7	26,8±0,7
1,8±0,02	defenders	7,4±0,01	13,2±0,08	14,1±0,04	94,6±1,12	28,1±0,7
1,6±0,04	attackers	8,3±0,06	12,3±0,05	12,3±0,1	119,4±0,71	26,9±0,7
1,9±0,03	defenders	7,8±0,04	13,9±0,04	14,8±0,07	118,8±0,6	27,4±0,9

Thus, the total duration of recurrent respiration of attacking rugby players increased from 30,6 minutes to 40,4 minutes ($p<0.001$) – by 23,4%, and for defenders from 32,3 minutes to 44,5 minutes ($p<0.001$) – by 27,4%.

The individual nature of changes in heart rate, frequency and depth of breathing under the influence of hypoxic training reflects the articulated nature of the interaction of the reactions of the respiratory system and blood circulation. So, if the subjects have decreased $FeCO_2$, then a decrease in heart rate is observed.

The positive effect of hypoxic training is evidenced by the fact that the function of breathing in such conditions increases its adaptive capacity. The materials of the study show that after the first respiration session in the tenth series, $FeCO_2$ decreased by 12,5 compared to the first series, FeO_2 – by 11,3% compared to the first series.

To determine the mechanisms for ensuring the duration of recurrent respiration, the regression analysis method was used, which establishes the role of each indicator of the oxygen transport system in providing hypoxic performance. The presented mathematical models of regression analysis were calculated taking into account the playing role of rugby players and show the interaction of intersystem and intrasystemic connections in the regulation of the duration of recurrent respiration after the first series of hypoxic effects. Formula 1 shows the significance and interrelation of the factors of the cardiorespiratory system of rugby players of the attack line.

$$T_{мin1}=3,75xFB+5,85xFB_{т\ exhalation}+3,19xHB-2,15xCO\ O_2-1,37+$$
$$+DO+1,05xFeCO_2+2,15xFeO_2+0,72xLV+0,17xFB_{т\ inhalation}\ \text{(formula 1)}$$

where $T_{Мin1}$ is duration of the recurrent breathing in the first session; FB is breathing frequency; $FB_{т\ exhalation}$ is the volume of the forced exhalation; HB is frequency of heart beats; DO is the respiratory volume; $CO\ O_2$ is the coefficient of the use of oxygen; $FeCO_2$ is the concentration of carbon dioxide in an exhalation; FeO_2 is the concentration of oxygen in the exhalation; LV is the vital capacity of lungs; $FB_{T\ inhalation}$ is a volume of the forced inhalation.

Using the inverse step regression method (formula 2), it was found that during the first respiration session, the determining factors for rugby players in the attack line were respiratory rate, forced expiratory volume and heart rate.

$$T_{min1}=6,85xFB+5,67xFB_{T\ exhalation}+3,75xHB \text{ (formula 2)}$$

where T_{min1} is duration of the recurrent breathing in the first session; FB is breathing frequency; $FB_{T\ exhalation}$ is the volume of the forced exhalation; HB is frequency of heart beats.

Rugby players of the defensive line had a slightly different correlation between the cardiorespiratory system and the duration of total respiration (formula 3).

$$T_{min2}=4,75xFB_{T\ exhalation}+2,75xHB+3,05xFeO_2–1,25xCO\ O_2–2,79xDO–$$
$$–1,53xFB+0,93xFeCO_2+0,57xLV+0,27xFB_{T\ inhalation} \text{ (formula 3)}$$

where T_{Min2} is duration of the recurrent breathing in the tenth session; $FB_{T\ exhalation}$ is the volume of the forced exhalation; HB is frequency of heart beats; FeO_2 is the concentration of oxygen in the exhalation; $CO\ O_2$ is the coefficient of the use of oxygen; DO is the respiratory volume; FB is breathing frequency; $FeCO_2$ is the concentration of carbon dioxide in an exhalation; LV is the vital capacity of lungs; $FB_{T\ inhalation}$ is the volume of the forced inhalation.

The most important factor in ensuring the duration of the return breath of rugby defenders in the first session is established (formula 4).

$$T_{min2}=5,75xFB_{T\ exhalation}+4,32xFB_{T\ inhalation}+2,75xHB \text{ (formula 4)}$$

where T_{Min2} is duration of the recurrent breathing in the tenth session; $FB_{T\ exhalation}$ is the volume of the forced exhalation; HB is frequency of heart beats; $FB_{T\ inhalation}$ is the volume of the forced inhalation.

The first series of studies carried out showed that the mechanism of urgent adaptation to the effects of hypoxic influences is limited by the range of functional capabilities of respiration and circulation and depends on the playing role of rugby players.

In the process of conducting ten sessions of recurrent respiration in a closed space, adaptation reactions have changed significantly. The multiple regression equation determined this kind of interrelation between cardiorespiratory factors that provide respiratory respiration in an enclosed space: of rugby players of the attack line (formula 5).

$$T_{Min2}=5,26xCO\ O_2+4,58xFB+3,21xFeO_2++5,32xHB+2,38xFB_{T\ exhalation}–$$
$$–1,47xDO+1,25xLV+3,51xFeCO_2+0,58xFB_{T\ inhalation} \text{ (formula 5)}$$

where T_{Min2} is duration of the recurrent breathing in the tenth session; $CO\ O_2$ is the coefficient of the use of oxygen; FB is breathing frequency; FeO_2 is the concentration of oxygen in the exhalation; HB is frequency of heart beats; $FB_{T\ exhalation}$ is the volume of the forced exhalation; DO is the respiratory volume; LV is the vital capacity of lungs; $FeCO_2$ is the concentration of carbon dioxide in an exhalation; $FB_{T\ inhalation}$ is the volume of the forced inhalation.

The inverse step regression equation determines the three main factors in ensuring the duration of the respiratory return of the rugby line of attack (formula 6).

$$T_{Min2}=6,27xCO\ O_2+3,74xHB+2,81xFeO_2 \text{ (formula 6)}$$

where T_{Min2} is duration of the recurrent breathing in the tenth session; $CO\ O_2$ is the coefficient of the use of oxygen; HB is frequency of heart beats; FeO_2 is the concentration of oxygen in the exhalation.

The rugby players of the defense line after the tenth session has somewhat different character of the relationship of factors that ensure the duration of recurrent respiration (formula 7).

$$T_{Min2}=7,38xFB_{T\ exhalation}+6,13xFB+4,85xDO+3,12xHB+3,15xFeCO_2–$$
$$–2,52xLV+6,32xCO\ O_2+2,57xFeCO_2+1,74xFB_{T\ inhalation} \text{ (formula 7)}$$

where T_{Min2} is duration of the recurrent breathing in the tenth session; $FB_{T\ exhalation}$ is the volume of the forced exhalation; FB is breathing frequency; DO is a respiratory volume; HB is frequency of heart beats; $FeCO_2$ is a concentration of carbon dioxide in the exhalation; LV is a vital capacity of lungs; $CO\ O_2$ is the coefficient of the use of oxygen; FeO_2 is the concentration of oxygen in the exhalation; $FB_{T\ inhalation}$ is the volume of the forced inhalation.

The inverse step regression equation defines the three main factors in ensuring the duration of the respiration of the players in the defence line in the tenth session (formula 8).

$$T_{Min2}=5,36xCO\ O_2+4,85xFB_{T\ exhalation}+1,85xFB_{T\ inhalation} \text{ (formula 8)}$$

where T_{Min2} is duration of the recurrent breathing in the tenth session; $CO\ O_2$ is the coefficient of the use of oxygen; $FB_{T\ exhalation}$ is the volume of the forced exhalation; $FB_{T\ inhalation}$ is the volume of the forced inhalation.

The carried out researches of influence of return breath have defined the mechanism of adaptation of oxygen transport system to conditions of a hypoxia which depend on specificity of competitive activity of rugby players.

Discussions

In Rugby League, the focus on the stage of specialized basic training is given the development of speed-strength training and the improvement of general technical preparedness. It is important at this stage to use the tools which increase the functional potential of the body of rugby players. The training of rugby players at this stage should provide the prerequisites for the maximum realization of their individual capabilities at the subsequent stage of the long-term sports path. Thus, the important role in the process of long-term training of athletes is played by the stage of specialized basic training, an urgent problem in which is the enhancement of the functionality of the body of rugby players.

In the process of training and competitive activities, adaptive mechanisms of the athlete's functional systems are formed, which provide the necessary level of special working capacity. Establishing objective information about the levels of functional changes makes it possible to determine the level of preparedness of athletes and effectively optimize the training process [2, 3, 22, 27], taking into account the specificity of the moving activity of players.

Hypoxic effects are widely used in the training process and are ones of the effective ways to enhance special performance in sports of submaximal intensity. Combining hypoxic training with the modification of physical loads allows to significantly improve the process of managing the preparation of rugby players [18, 20, 29, 31].

Adaptation of the body's systems to the conditions of hypoxic hypercapnia is a complex integrated reaction in which intrasystemic and intersystem rebuilding of the organism is manifested, which determines the specific performance of the rugby players [11, 23, 26]. This scientific position is confirmed in our studies in the process of influence of normobaric interval hypoxia. It was found that, after the first series of interval hypoxia, the main adaptation factors were respiration rate and heart rate. After the tenth session, the main factors of adaptation of hypoxia were the oxygen utilization factor (CO O_2) and oxygen concentration in the exhaled air (FeO_2). The materials of our studies are confirmed by data that show that with the high intensity of motor actions in confrontations with rivals in the current game situation, the provision of efficiency is the increase in the functionality of the oxygen transportation system [6, 8, 9].

At the same time, fundamental studies [7, 20, 30] indicate that in order to achieve high sports results, the level of oxygen consumption, the energetic cost of physical loads and adaptive reserves of the organism, is significant in Rugby League [5, 10].

Our results are confirmed by the results of the study [22, 23], which indicate that in the initial stages of hypoxic preparation, the increase in FeO_2 is a stimulator of increased ventilation of the lungs, which is increased by respiratory rate with a slight decrease in the depth of breathing.

Conclusions. Analyzing the materials of these studies, there is a variety of conclusions that characterize the mechanisms of adaptation to hypoxic loads. In our opinion, they all have the right to exist because all these studies were conducted in different conditions, with different goals and different methods.

In our studies, the obtained results are confirmed by literature data on the mechanisms of adaptation, however, depending on the specifics of the competitive activity, the arsenal of adaptation factors changes. So, the leading factors of adaptation to the hypoxia of rugby players are the attack lines CO O_2, HB, FeO_2, and the players in the defence line – CO O_2, $FB_{\text{т exhalation}}$, $FB_{\text{т inhalation}}$.

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