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Original Article

Hypoxic capacity as the basis for sport efficiency achievements in the men's 400-meter hurdling

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Abstract:
Physiological indicators say a lot about the preparedness and performance of athletes. We considered the basic parameters to be Vo2max, AeT, AT, lactate and some others. These athletes' parameters progress throughout the annual training cycle (ATC). The ideal curve representing them graphically has a sinusoidal character. It either rises up or goes down towards the peak of the season according to the specific indicator.
We have chosen the following diagnostic indicator – the dynamics (progress) of aerobic and anaerobic threshold of a subject who represents Slovakia in the cross and winter triathlon. Required data were obtained from training logs and on the basis of tests carried out under laboratory conditions. Using a treadmill, we determined the speed according to particular threshold loads (AT and AeT), correlated them with training indicators and subsequently identified dependencies. We observed not only their current impact on performance but also the impact of training indicators. The results we obtained uncovered errors and deficiencies in the subject's training process. We have tried to remove them and choose a more appropriate solution and training schedule. Purpose: To establish the dependence of the result of running the 400-meters men's hurdling on the level of hypoxic capacity. Results for: foundation for the structure of training sessions and sessions anaerobic impact consisted of a 10-days microcycle. After each training session loading of hypoxia was applied alternately: 10 sessions of interval hypoxia during rebreathing in the closed space and anaerobic hopping 60 seconds test Bosco S., Luhtanen P., Komi P.V. (1983). During rebreathing into closed space the indices of cardiovascular system (systolic and diastolic blood pressure, heart rate), and respiratory tract (pulmonary ventilation, respiratory rate, the utilization rate of O2, CO2 accumulation percentage and the percentage of O2) have been fixed. The use of regression analysis made it possible to identify the main factors of anaerobic performance to achieve the lowest index running time to overcome the 400-meters hurdling. Research materials indicate the need for hypoxic training as improving adaption to hypoxia is the main mechanism for improving athletic performance in the men's 400-meters hurdling. Conclusions: The findings deepen scientific data about the features of adaptive mechanisms to this type of competitive activity.
Key words: adaptation, hypoxic performance, running the 400-meters hurdling, anaerobic power.

Introduction

The level of sporting achievements is formed on the basis of functionality, providing a special performance in certain kinds of sports [16, 17, 27]. Physiological laws are special performance enhancing mechanisms of adaptation of the body systems to the effects of physical activity [21, 22].Therefore, the problem of adaptation to physical stress is one of the most important in the training of athletes [1, 4, 9, 10]. In every kind of sport, there are general principles and patterns of adaptation to physical loads. However, the important point in this regard is the definition specific to this kind of sport manifestations special performance [8, 25]. Thus, the basis for achieving results in the men's 400 m hurdling are individual sensitivity to hypoxia and hypoxic performance [24]. Therefore, registration of adaptive responses to the effects of hypoxic loads is one of the factors of management of training process of runners on 400 m hurdling. [28] This determined the relevance of that study.

Materials and methods.

Participants

The study involved 14 runners in the men's 400 m hurdling at the age of 16-17 years who have had the level of training of the first sports category, and the candidate for master of sports.

The research design supposed to establish the level of influence of hypoxia on the organism of athletes by rebreathing into the Douglas bag of 30 liters. The sportsmen breathed the air from the bag, and the exhaled air

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through a hose back into the bag again. It was fixed the time of possible return of breathing exhaled air [19, 20, 22].

To establish the special hypoxic endurance of young athletes it was used the prolonged hypoxic test as described in the 60-th sekudngo hopping test Bosco S., Luhtanen P., Komi P.V. (1983).In the laboratory, of Kharkiv State Academy of Physical Culture it was developed the platform, recording the flight time and repulsion in contact with the support. During jumps performed consistently circuit (for support) and the opening (unsupported position) of the microswitch located under the surface of the platform C. Bosco, Luhtanen P., Komi P.V. (1983).

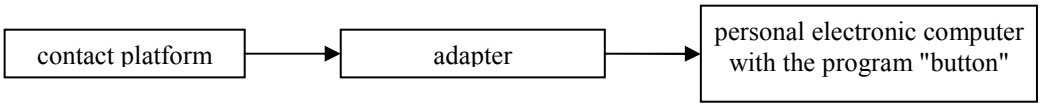

Fig. 1.The block diagram

To assess the condition of the oxygen-transport system determined by such indicators: HB is frequency of heart beats; FR is breathing frequency; LV is a vital capacity of lungs; DO is a respiratory volume; CO O_2 is a coefficient of the use of oxygen; $FB_{т\ exhalation}$ is the volume of the forced exhalation; $FB_{т\ inhalation}$ is the volume of the forced inhalation; $FeCO_2$ is a concentration of carbon dioxide in an exhalation.

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.

In order to determine the level of special physical performance it was determined by the correlation coefficient to establish the mechanisms of adaptation to hypoxia conditions we apply regression analysis, which defines the role of each factor in hypoxic performance. To determine the most important factors in ensuring the adaptation to hypoxic conditions it was used the method of stepwise backward regression.

Results

Research Series rebreathing recorded duration in which it maintained a certain frequency. Clear linear relationship is established between indices of breath duration, increase and decrease $FeCO_2$ FeO_2 in exhaled air.

Research materials show a gradual decrease in the duration of each series of rebreathing and a significant change in the ratio of CO_2 and O_2 in exhaled air. Thus, the duration of rebreathing in series tenth as compared with the first dropped by 90.7%. This in turn increased the $FeCO_2$ 61.5% and reduced FeO_2 45.2% ($p<0.001$).

In the tenth series of rebreathing tidal volume (DO_2) decreased by 1.8%, that caused the increase of respiration volume by 45% due to breathing frequency (BF). Increasing of frequency of heart beats by 38.3% and reducing CO O_2 by 28.5% ($p<0.001$).

Analyzing the study materials it can be argued that the constant increase $FeCO_2$ throughout the series rebreathing is a stimulant increase in pulmonary ventilation, the value of which increased by 45%.

Increased frequency of heart beats paralleled increase respiration rate, and amounted to 38.5% ($p<0.001$).

The results correspond to the data in the literature studies [9, 10, 11, 16] which have shown that increasing to 7% $FeCO_2$ causes the increase in respiratory rate. At lower values the accumulation of CO_2 the significant increase in respiratory rate was observed. This situation explains the decrease in the sensitivity of the respiratory center of runners on 400 m hurdling to such strong incentive, as CO_2, that is a consequence of long-term adaptation to the specific conditions of training and competitive activities.

Thus, we can conclude that during rebreathing compensatory mechanism is to improve the performance ventilation and heart rate based on the study of materials.

Carrying normobaric interval hypoxic training of runners on 400 m hurdling promoted their adaptation capabilities. Thus, the total duration of rebreathing in the tenth session was 42.5 min., 12.5% more than in the first session ($p <0.001$). The evidence of increasing adaptive capacity in hypoxia is a change in performance and $FeCO_2$ FeO_2. So, after the first session of the tenth series $FeCO_2$ increased by 4.9% and FeO_2 decreased by 6.5%. After the tenth session $FeCO_2$ rose only 1.5%, and FeO_2 decreased by 2.5% ($p<0.001$).

Through exposure to hypoxic interval training our aim was to establish not only the level of hypoxic manufacturer, and determine the impact of hypoxic treatments on athletic performance.

To this end, compared the duration of individual sessions rebreathing barrier with the time of running distance. The research materials indicate (table. 1, 2), with the decrease in the time rebreathing increases time to cover the distance from the barrier to the barrier. As can be seen, especially large dependence sports results from time to time rebreathing barrier appears from the seventh, when the time rebreathing decreased by 30%, and the

time of running to the seventh barrier has increased by almost 50%. Hypoxic interval training helped to increase the speed to overcome barriers. At the end of the experiment there is significant increase in the speed of running athletes ($p<0.001$).

Table 1. The ratio of temporary parameters to overcome the distance of 400 m hurdling and rebreathing in the closed space at the beginning of the experiment

Time index	1	2	3	4	5	6	7	8	9	10
Of running time 10 distance barriers (s.)	7,65	11,87	16,59	21,44	26,32	30,51	36,12	40,00	46,20	51,70
Rebreathing time (min.)	7,52	6,73	5,58	4,00	3,11	2,61	2,21	1,83	1,68	0,97

Table 2. The ratio of temporary parameters to overcome the distance of 400 m hurdling and rebreathing in the closed space at the end of the experiment

Time index	1	2	3	4	5	6	7	8	9	10
Of running time 10 distance barriers (s.)	6,81	11,32	15,84	21,27	25,90	29,70	35,61	39,50	45,00	50,30
Rebreathing time (min.)	8,21	7,12	6,61	4,52	3,62	2,65	2,83	1,88	1,72	1,70

Application of correlation analysis confirmed the dependence of the running speed of the hypoxic stability where the correlation coefficients were at r=0,64-0,76. The highest level of significance between the index determination the time to overcome the seventh of the barrier and the duration of rebreathing in the seventh series of r=0,78-0,76.

To characterize the anaerobic performance of runners on 400 m hurdling used 60-second test jump Bosco S., Luhtanen P., Komi P.V. (1983), which allows to evaluate the possibility of athletes in maintaining the maximum pace and power of work. For a detailed analysis of the anaerobic capacity we estimated flight time performance and support phases for 15 s. (table. 3).

Table 3. Indicators and time of flight reference phase and anaerobic power runners on 400 m hurdling at different stages of the experiment (M ± m)

Group	Initial data			After months of training			At the end of mesocycle		
	FT, s.	SPT, s.	Wa, w	FT, s.	SPT, s.	Wa, w	FT, s.	SPT, s.	Wa, w
16-18 years	0,63±0,023	0,19±0,017	6,60±0,12	0,62±0,05	0,18±0,002	6,80±0,13	0,14±0,003	0,17±0,002	7,8±0,13

where FT is flight time, SPT is support phase time, Wa is anaerobic performance

Describing the results of research it can be concluded that the increase in anaerobic power is manifested in the increase of the time interval during which it is possible to maintain a high pace of work. A significant increase in the time of the flight phase at the end of the experiment indicates an increase in the anaerobic endurance.

During the hopping test monitored the heart rate. Comparative analysis of heart rate parameters of running at a distance of 400 m, and during the test, which showed an identical heart rate response. Therefore, we recommend hopping test is used as an integral component of special speed-strength endurance.

In order to establish adaptation mechanisms to maximize the performance of anaerobic method was used regression analysis, which establishes the role of each factor in ensuring the hypoxic performance, as a basis to achieve sports results in the men's 400-meters hurdling.

These mathematical models of regression analysis indicate the level of importance of each factor in the achievement of sports results in the men's 400 m hurdling (formula 1).

$$T_s=4,57xFB+8,57xDO+3,75xHB-2,57T_{min1}-2,37xCO\ O_2$$
$$-1,73+FB_{т\ exhalation}+0,97xFeCO_2+3,05xFO_2+2,27xWa+0,67xLV+$$
$$+0,31x\ FB_{т\ inhalation} \text{ (formula 1)}$$

where T_s is result in the men's 400-meters hurdling; FB is breathing frequency; DO is a respiratory volume; HB is frequency of heart beats; T_{min1} is rebreathing total time in the first session; $CO\ O_2$ is a coefficient of the use of oxygen; $FB_{т\ exhalation}$ is a volume of the forced exhalation; $FeCO_2$ is a concentration of carbon dioxide in an exhalation; FeO_2 is a concentration of oxygen in an exhalation; Wa is anaerobic power of inspiration; LV is a vital capacity of lungs; $FB_{т\ inhalation}$ is a volume of the forced inhalation.

To determine the most important factors in achieving athletic performance formula backward stepwise regression was used (formula 2).

$$T_s=6,85xT_{min1}+3,35xHB \text{ (formula 2)}$$

where T_s is result in the men's 400-meters hurdling; T_{min1} is rebreathing total time in the first session; HB is frequency of heart beats.

Thus, the mechanism for maintaining hypoxic performance in the men's 400-meters hurdling is limited by the level of functional activity of the respiratory and circulatory systems.

At the end of the experiment after the tenth session of interval normobaric hypoxia adaptive response have changed significantly, which contributed to increased results in the men's 400-meters hurdling with 58,27 s. and 56,21 s. ($p<0.001$).

Multiple regression equation sited factors set in this order (formula 3).

$$T_s=8,36xCO\ O_2+6,48xFeO_2+5,32xT_{min2}+5,25xWa+4,32xFB+3,12xDO–2,81xHB–$$
$$2,25xLV+2,15xFeCO_2+1,58xFB_{т\ exhalation}+1,37xFB_{т\ inhalation} \text{ (formula 3)}$$

where T_{s2} is time to overcome the distance of 400 m hurdling; CO O_2 is a coefficient of the use of oxygen; FeO_2 is a concentration of oxygen in an exhalation; $T_{minн2}$ is the duration of rebreathing at the end of the experiment; Wa is anaerobic power; FB is breathing frequency; DO is a respiratory volume; HB is frequency of heart beats; LV is a vital capacity of lungs; $FeCO_2$ is Voltage carbon dioxide in exhaled air; $FB_{т\ exhalation}$ is a volume of the forced exhalation; $FB_{т\ inhalation}$ is a volume of the forced inhalation.

The use of reverse stepwise regression formula has identified three main factors in achieving results in the men's 400 m hurdling (formula 4).

$$T_{c2}=6,75xWa+5,27x;\ CO\ O_2+4,37xT_{min2}$$

где T_{s2} is result in the men's 400-meters hurdling at the end of the experiment; Wa is anaerobic power of inspiration; CO O_2 is a coefficient of the use of oxygen; T_{min2} is the total time of rebreathing in the tenth session.

Thus, studies the impact of normobaric interval training indicates that the basis for achieving athletic performance in the men's 400-meters hurdling is the level of hypoxic anaerobic performance.

Discussion

Running the 400-meters and particularly hurdling is one of the most difficult sports, which not without reason is called "running killer" (Quercetani R.L., 2005). This is explained by the fact that the motor activity of the athletes is a combination of speed and strength endurance to prolonged exposure to normobaric hypoxia [11, 18, 22].

Sporting achievements in this kind undoubtedly depend on an integrated approach to the system of training athletes. Conditional split training system to identify one of the major parties would make it possible to organize awareness of the laws of development of the body systems, which provide motor activity in a particular sport [3, 15, 18]. However, in actual training process, none of the parties to prepare does not appear isolated, and is in constant interdependence.

It is proved that the achievement of sports results is only possible if all sides orchestration training [2, 3, 6]. This scientific position is particularly evidenced in the preparation of runners on 400 m and 400 m hurdling, where the display of speed-strength endurance depends on the adaptability to hypoxic [1, 12, 14, 18].

Most scientific studies of adaptive reactions of the organism to hypoxia are limited to functional changes in the cardio-respiratory system [5, 8, 9].

However, the limited amount of research that treat complex adaptive regularity during training under normobaric hypoxia.

Combining with hypoxic effects of physical activity modification can significantly improve the preparation process of managing athletes in sports submaximal intensity [12, 14, 16, 25].Research Heikki Rusko (2004) shows that the alternation hypoxic and normobaric loads enhances the effectiveness of adaptation processes and significantly reduce the harmful effects of chronic hypoxia.

The positive effect of hypoxic stress has been produced by research of Sybil M.G., Svysch Y.S. (2009), which shows that the increase in adaptive capacity happens due to the preservation of the biochemical balance.

Adaptation mechanism to hypoxic hypercapnia is a complex integrated reaction in which manifested intra and inter-system rebuild the body, which leads to the development of a special performance of runners on 400 m hurdling [4, 5, 21, 23]. This scientific position is confirmed in our study. It was found that the combination of rebreathing T 60 seconds load of hopping with maximum intensity helped to improve the stability of hypoxic and sports indices. The main factors to achieve maximum athletic performance in the men's

400 m hurdling are Wa is anaerobic power; KIO_2 is coefficient of oxygen utilization and T_{min2} is time rebreathing ten Sensei [7, 8, 15].

However, the studies [23, 24] indicate that in order to achieve good indices of results in the men's 400 m hurtling the important factor is the level of oxygen consumption, energy cost of physical activity and adaptation reserves of the organism.

One mechanism for adaptation to hypoxic stress rate is gas exchange in the lungs and blood delivery of oxygen to working muscles [8, 19, 22].

Studies [9, 11] indicate that the initial stages of hypoxic training $FeSO_2$ increase in exhaled air is a stimulant ventilation, which is implemented by the frequency of breathing with a slight decrease in the depth of breathing. This position has been confirmed in our studies [12, 13, 14, 18] at the beginning of the experiment.

Conclusions

Analyzing the materials of our investigations and literature data there is a variety of conclusions and judgments that characterize the mechanisms of adaptation to hypoxic stress. In our view they all have the right to exist because all of these studies were conducted in different settings, with different goals and different methods. However, they confirm the truth of being human body adaptation mechanisms to external forces.

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