Hypoxic training as the basis for the special performance of karate sportsmen

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Abstract: Purpose: to develop a method of hypoxic training to increase the level of special physical fitness of karate sportsmen. The research tasks: to carry out the analysis of scientific and methodological literature on the determination of the laws of adaptation of the athlete's organism to the conditions of hypoxia; to determine the state of special physical preparedness of karate sportsmen of 16-17 years old; to develop the method of hypoxic training by the method of recurrent respiration into the closed space; To determine the most important factors in raising the level of special physical preparedness of karate sportsmen aged 16-17. Results: Ten sessions of hypoxic exposure during recurrent respiration in the closed space were performed. Interval hypoxic training was carried out on the basis of the body's reaction to the gradual decrease the volume of oxygen in the respiratory air. During the reverse breathing, the parameters of the cardiovascular system and the respiratory system were recorded in the closed space. The use of regression analysis made it possible to determine the main factors ensuring the duration of recurrent respiration. Research materials indicate studying testify the need for carrying out hypoxic training, since the increase in adaptability to hypoxia is the mechanism for the development of the special working capacity of karate sportsmen of 16-17 years old. Conclusions: the results of the study deepen information about the features of adaptive mechanisms to certain competitive activities. Inclusion of interval hypoxic training in the training process contributed to a more significant increase in the anaerobic performance of karate sportsmen of 16-17 years old.

Key words: adaptation, karate, recurrent respiration, hypoxia, normobaric hypoxia.

Introduction
The problem of training karate sportsmen of 16-17 years old is characterized by the fact that in the process of physical training it is necessary to solve specific sports problem [12, 19].

The motor qualities that contribute to the mastery of technical elements of karate ensure the ability of athletes to manifest specific motor functions: static and dynamic balance, accuracy of movements after rotation, maximum frequency of shock movements, accuracy of dynamic and spatial-temporal parameters of movements, restructuring of motor activity and coordination of movements, Elements [2, 10, 19].

It should be noted that all speed-power competitive activities take place under conditions of severe hypoxic action, and therefore the level of adaptability to hypoxia and individual sensitivity to lack of oxygen determine the effectiveness of competitive activity [4, 26].

The lack of objective data on the technology of hypoxic preparation of karate sportsmen has determined the direction of our studies.

Materials and methods.
Participants. In the studies, 18 karate sportsmen aged 16-17 years took part, having the level of training of the first sports category and a candidate for master of sports.

The main research methods: analysis and generalization of scientific and methodological literature, the method of recurrent respiration, frequency of heart beats (HB), coefficient of the use of oxygen (CO2), increase in pulmonary ventilation (respiration volume litre), breathing frequency (FB), respiratory volume (DO), concentration of carbon dioxide in an exhalation (FeCO2), concentration of oxygen in the exhalation (FeO2), pedagogical testing of special physical readiness.

Study design
Hypoxic training was conducted after having rest after the main training load. Hypoxic training was breathing in the closed space by the method of return breathing into the bag of Douglas to failure. Normobaric hypoxic training lasted 10 sessions of 10 series in each session. The duration of respiration in each serie was determined.
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 hypotheses 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. With the purpose of establishment of mechanisms of adaptation in providing of maximal possibility of the recurrent breathing the regressive analysis which determines the role of every factor in the hypoxic productivity was used in the reserved space. Application of incremental reverse regression enables to define the most meaningful factors in providing of adaptation to the hypoxic conditions.

Results of the study and their discussion

Preliminary testing of special physical preparedness has been made for determination positive influence of interval hypoxic training upon special capacity (table 1).

Table 1. Initial indicators of special physical readiness karate sportsmen of 16-17 years (n=18)

<table>
<thead>
<tr>
<th>Tests</th>
<th>Experimental group (n=9)</th>
<th>Control group (n=9)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>σ</td>
</tr>
<tr>
<td>Static balance on the right foot, seconds</td>
<td>22,67</td>
<td>1,36</td>
</tr>
<tr>
<td>Static balance on the left leg, seconds</td>
<td>29,98</td>
<td>3,78</td>
</tr>
<tr>
<td>Dynamic balance with the right foot, seconds</td>
<td>18,55</td>
<td>1,42</td>
</tr>
<tr>
<td>Dynamic balance with the left foot, seconds</td>
<td>19,90</td>
<td>3,26</td>
</tr>
<tr>
<td>5 side impacts to the upper level by lifting the right foot, seconds</td>
<td>5,68</td>
<td>0,79</td>
</tr>
<tr>
<td>5 side impacts to the upper level by lifting the left foot, seconds</td>
<td>6,53</td>
<td>0,83</td>
</tr>
<tr>
<td>Side impacts with the right foot in the middle level for 10 seconds (quantity)</td>
<td>19,50</td>
<td>1,37</td>
</tr>
<tr>
<td>Lateral blows left foot in the middle level for 10 seconds (quantity)</td>
<td>17,85</td>
<td>1,13</td>
</tr>
<tr>
<td>Two hands and one side kick into the body of the leg 5 series, seconds</td>
<td>13,14</td>
<td>0,85</td>
</tr>
<tr>
<td>Counterattack attack, seconds</td>
<td>12,83</td>
<td>1,65</td>
</tr>
</tbody>
</table>

The analysis of the initial indicators of special physical preparedness indicates that in both groups they do not have statistically significant differences (p>0.05).

During the series of breathing in the confined space, this time was fixed, at which a certain frequency of respiration was maintained. Analysis of the results of the study indicates an explicit linear relationship between the duration of respiration in confined space and the increase in the index of FeCO₂ and the decrease in FeO₂ in the exhaled air (table 2). Thus, the duration of recurrent respiration at the beginning of the first series in the tenth session decreased by 93.33%. This was facilitated by the increase in FeCO₂ by 82.5%. It is characteristic that the tension of FeO₂ in the exhaled air after the tenth session decreased by 59.4%.

Table 2. Indicators of the oxygen transport system of karate sportsmen of 16-17 years at the beginning of hypoxic training (n=18)

<table>
<thead>
<tr>
<th>T, min.</th>
<th>FeCO₂, %</th>
<th>FO₂, %</th>
<th>DO₂, litre</th>
<th>Breathing frequency, quantity</th>
<th>Respiration volume litre per min.</th>
<th>Heart beats per min.</th>
<th>Coefficient O₂, ml/per min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,40±0,03</td>
<td>2,80±0,03</td>
<td>19,30±0,07</td>
<td>0,66±0,01</td>
<td>10,50±0,09</td>
<td>8,64±0,02</td>
<td>65,00±0,70</td>
<td>32,30±1,40</td>
</tr>
<tr>
<td>7,30±0,07</td>
<td>5,20±0,01</td>
<td>17,00±0,04</td>
<td>0,62±0,04</td>
<td>19,00±0,08</td>
<td>9,87±0,01</td>
<td>71,20±0,71</td>
<td>33,70±0,90</td>
</tr>
<tr>
<td>5,60±0,03</td>
<td>5,30±0,02</td>
<td>15,30±0,01</td>
<td>0,63±0,07</td>
<td>19,30±0,07</td>
<td>10,93±0,03</td>
<td>71,00±0,90</td>
<td>35,50±0,70</td>
</tr>
<tr>
<td>4,00±0,06</td>
<td>6,10±0,01</td>
<td>14,20±0,04</td>
<td>0,60±0,03</td>
<td>18,60±0,04</td>
<td>11,40±0,05</td>
<td>74,30±1,10</td>
<td>31,40±0,40</td>
</tr>
<tr>
<td>3,10±0,02</td>
<td>6,30±0,04</td>
<td>14,00±0,01</td>
<td>0,58±0,01</td>
<td>17,20±0,03</td>
<td>11,38±0,07</td>
<td>82,10±1,03</td>
<td>29,50±1,11</td>
</tr>
<tr>
<td>2,60±0,01</td>
<td>6,70±0,02</td>
<td>13,80±0,04</td>
<td>0,62±0,08</td>
<td>19,10±0,04</td>
<td>11,55±0,03</td>
<td>94,50±1,12</td>
<td>30,30±0,70</td>
</tr>
<tr>
<td>2,20±0,03</td>
<td>7,20±0,02</td>
<td>13,00±0,08</td>
<td>0,60±0,04</td>
<td>20,00±0,07</td>
<td>12,16±0,02</td>
<td>100,10±1,43</td>
<td>29,10±0,90</td>
</tr>
<tr>
<td>1,80±0,02</td>
<td>7,40±0,03</td>
<td>12,40±0,08</td>
<td>0,58±0,05</td>
<td>28,30±0,05</td>
<td>13,14±0,05</td>
<td>105,20±1,32</td>
<td>26,60±0,70</td>
</tr>
<tr>
<td>1,70±0,03</td>
<td>7,60±0,02</td>
<td>12,10±0,09</td>
<td>0,56±0,07</td>
<td>20,10±0,06</td>
<td>13,50±0,05</td>
<td>107,50±0,97</td>
<td>26,10±1,10</td>
</tr>
<tr>
<td>0,70±0,04</td>
<td>7,80±0,01</td>
<td>11,80±0,07</td>
<td>0,55±0,03</td>
<td>20,40±0,07</td>
<td>13,50±0,07</td>
<td>108,50±1,22</td>
<td>27,00±1,20</td>
</tr>
</tbody>
</table>

It is worth noting that the increase frequency of heart beats (HB) is parallel to the indicators of pulmonary ventilation: frequency of heart beats (HB) by 65.2%, and the increase in pulmonary ventilation by 62.5%.

It is also established that the compensatory mechanism during recurrent respiration in the enclosed space is precisely of the increase in pulmonary ventilation and frequency of heart beats (HB). Conducting normobaric interval training for 10 sessions at the end of each mesocycle contributed to the increase in the level of special physical preparedness (table 3) and adaptive abilities of karate sportsmen of 16-17 years (table 4).
The results of the study (table 4) show that the total duration of recurrent respiration in karate sportsmen of 16-17 years increased from 33.6 minutes at the beginning of the experiment to 54.6 minutes at the end (p<0.001).

The indices of static and dynamic balance after sessions of hypoxic training increased by two (p<0.001). Shock movements were of particular interest, since the result of the match depends on their number and intensity. Thus, the time of execution of the strikes to the upper level by the right and left leg decreased by 89.4%, and the number of strokes in the middle level increased by 11.6 times (p<0.001).

During a duel judges determine the strongest and most accurate blows on the basis of which they give victory to one of the karate players. Net victory – the "ippon" score is given to the karate sportsmen: 1. for two clean kicks on the head; 2. for the technique carried out, on the opponent's body by hands or feet, after which the opponent cannot continue the fight; 3. for the technique carried out by kicking the opponent's legs and also if he cannot continue the fight. The floor of victory is given to the karate sportsmen: 1. for one clean kick with the feet on the head; 2. for the technique performed on the opponent's body by hands or feet, after which the opponent can continue the fight; 3. for the technique carried out by kicking the opponent's legs and also if he can continue the fight. The victory in a duel is determined by the preference of exact strikes. The art of their fulfillment depends on special anaerobic endurance.

Analysis of the results of the study (table 4) shows that the total duration of recurrent respiration in karate sportsmen of 16-17 years increased from 33.6 minutes at the beginning of the experiment to 54.6 minutes at the end (p<0.001).

The individual character of frequency of heart beats (HB), breathing frequency (FB), respiratory volume (DO) under the influence of hypoxic training reflects the articulated nature of the interaction of the respiratory and circulatory system. So, if the athletes have decreased FeCO₂, then there is the decrease HB.

Materials of the study testify that in the tenth series, the FeCO₂ index decreased in the tenth session by 28.3% compared to the first series, and the FeO₂ index increased by 35.6%.

The increase in anaerobic productivity contributed to the increase in competitive performance – the performance of accurate shocks. So, their number during the fight increased from 4.2±0.07 to 5.6±0.03 (p<0.001).

With the purpose of determining the mechanisms of hypoxic adaptation of the organism of karate sportsmen of 16-17 years, a regression analysis method was used that establishes the role of each indicator of the oxygen transport system in providing hypoxic performance. The presented mathematical models show the interaction of intersystem and intrasystemic connections in the regulation of the duration of recurrent respiration.

So, after the first series of hypoxic training (formula 1) shows the significance and interrelation of the factors of the cardiorespiratory system of karate sportsmen of 16-17 years.

\[ T_{min} = 4.57 \times FB + 3.58 \times FB_{exhalation} + 3.39 \times HB - 1.75 \times CO_{2} - 1.37 \times DO + 1.05 \times FeCO_{2} + 2.15 \times FeO_{2} + 0.92 \times LV + 0.17 \times FB_{inhalation} \] (formula 1)
where \( T_{\text{min1}} \) is duration of the recurrent breathing in the first session; \( FB \) is breathing frequency; \( FB_{\text{exhalation}} \) is the volume of the forced exhalation; \( HB \) is frequency of heart beats; \( DO \) is the respiratory volume; \( CO_{2} \) 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; \( FB_{\text{inhalation}} \) is a volume of the forced inhalation.

To determine the most significant indicators in ensuring the duration of recurrent respiration in the closed space, the inverse step regression method was used, which determined the most regular factors (formula 2).

\[
T_{\text{min1}} = 5.63xFB + 5.37xFB_{\text{exhalation}} + 3.93xHB \quad (\text{formula 2})
\]

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

In the process of research, it is very important to establish the level of competitive performance – the number of accurate hits in at one and a half minute fight and on what factors this performance depends.

The resulted mathematical models of regression analysis show the significance level of each factor in achieving the sporting result (formula 3).

\[
Indk_t=4.75xT_{\text{min1}} + 6.39xDO + 3.75xFB + 2.57xHB – 2.73xCO_{2} – 1.73x
xFB_{\text{exhalation}} + 1.65xFeO_{2} + 3.05xFeCO_{2} + 2.17xLV + 0.97xFB_{\text{inhalation}} \quad (\text{formula 3})
\]

where \( Indk_t \) is the number of accurate shocks; \( T_{\text{min1}} \) is the duration of recurrent respiration; \( DO \) is the respiratory volume; \( FB \) is breathing frequency; \( HB \) is the frequency of heart beats; \( CO_{2} \) is the coefficient of the use of oxygen; \( FB_{\text{exhalation}} \) is the volume of the forced exhalation; \( FeO_{2} \) is the concentration of oxygen in the exhalation; \( FeCO_{2} \) is the concentration of carbon dioxide in an exhalation; \( LV \) is the vital capacity of lungs; \( FB_{\text{inhalation}} \) is the volume of the forced inhalation.

Applying the inverse step regression formula, the most important factors in ensuring the competitive activity of karate sportsmen of 16-17 years of precise shocks (formula 4) are established.

\[
Indk_t = 6.93xT_{\text{min1}} + 5.27xFB_{\text{exhalation}} + 3.35xHB \quad (\text{formula 4})
\]

where \( Indk_t \) is the number of accurate shocks; \( T_{\text{min1}} \) is the duration of recurrent respiration; \( FB_{\text{exhalation}} \) is the volume of the forced exhalation; \( HB \) is the frequency of heart beats.

Thus, the mechanism of hypoxic performance is limited by the state of the functional activity of the oxygen transport system.

Conduction of hypoxic training in the form of recurrent respiration into confined space promoted a significant increase in the adaptability of karate sportsmen of 16-17 years to the conditions of anaerobic motor activity. The multiple regression equation determined this kind of interrelation of cardiorespiratory parameters that ensure the duration of recurrent respiration in the closed space (formula 5).

\[
T_{\text{min2}} = 6.73xFB_{\text{exhalation}} + 6.21xFB + 5.45xDO + 3.47xHB + 3.15xFeCO_{2} – 2.75xLV + 6.32xCO_{2} + 2.15xFeO_{2} + 1.74xFB_{\text{inhalation}} \quad (\text{formula 5})
\]

where \( T_{\text{min2}} \) is duration of the recurrent breathing in the tenth session; \( FB_{\text{exhalation}} \) is the volume of the forced exhalation; \( FB \) is breathing frequency; \( DO \) is the respiratory volume; \( HB \) is frequency of heart beats; \( FeCO_{2} \) is the concentration of carbon dioxide in an exhalation; \( FeO_{2} \) is the coefficient of the use of oxygen; \( FeO_{2} \) is the concentration of oxygen in the exhalation; \( LV \) is the vital capacity of lungs; \( FB_{\text{inhalation}} \) is the volume of the forced inhalation.

The stepwise regression regression equation determined three main factors in ensuring the duration of recurrent karate sportsmen of 16-17 years in the tenth session (formula 6).

\[
T_{\text{min2}} = 5.36xCO_{2} + 4.85xFB_{\text{exhalation}} + 3.85xFB_{\text{inhalation}} \quad (\text{formula 6})
\]

where \( T_{\text{min2}} \) is duration of the recurrent breathing in the tenth session; \( CO_{2} \) is the coefficient of the use of oxygen; \( FB_{\text{exhalation}} \) is the volume of the forced exhalation; \( FB_{\text{inhalation}} \) is the volume of the forced inhalation.

After the tenth session of the final tenth series of hypoxic training, the regression analysis equation indicates that the adaptive mechanism for providing competitive activity has changed somewhat. This allows us to determine new, more significant factors in achieving the number of determinants of accurate shocks (formula 7).

\[
Indk_t = 6.75xT_{\text{min2}} + 5.79xFB_{\text{inhalation}} + 4.37xFB_{\text{exhalation}} + 3.95xCO_{2} + 3.25xFB + 2.95xHB – 1.75xFeO_{2} + 2.73xFeCO_{2} + 1.95xLV + 2.03xDO \quad (\text{formula 7})
\]

where \( Indk_t \) is the number of accurate shocks; \( T_{\text{min2}} \) is duration of the recurrent breathing in the tenth session; \( FB_{\text{inhalation}} \) is the volume of the forced inhalation; \( FB_{\text{exhalation}} \) is the volume of the forced exhalation; \( CO_{2} \) is the coefficient of the use of oxygen; \( FB \) is breathing frequency; \( HB \) is frequency of heart beats; \( FeCO_{2} \) 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; \( DO \) is the respiratory volume.

The inverse step regression equation defines the three main factors in providing competitive performance (formula 8).

\[
Indk_t = 7.22xT_{\text{min2}} + 5.17xHB + 3.75xFB_{\text{inhalation}} \quad (\text{formula 8})
\]

where \( Indk_t \) is the number of accurate shocks; \( T_{\text{min2}} \) is duration of the recurrent breathing in the tenth session; \( HB \) is frequency of heart beats; \( FB_{\text{inhalation}} \) is the volume of the forced inhalation.
Thus, the conducted studies of the influence of hypoxic normobaric training indicate that with increasing hypoxic stability, the effectiveness of the competitive activity of karate sportsmen of 16-17 years is significantly increased.

Discussion
Considering the problem of training karate sportsmen of 16-17 years, it was established that in the process of physical training it is necessary to solve problems specific to this sport [2, 6, 7].

The structure of physical preparedness, as a complex, multifactor indicator, was considered in many sports [11, 27, 30].

In accordance with the studies [12, 13, 20], it is established that there are single studies of this problem in the preparation of karate sportsmen who do not create an idea of the versatility of individual components of special physical preparedness and the role of each of them in the formation of complexly coordinated techniques.

Karate, as a sport, is characterized by intensive motor activity, which is carried out under anaerobic conditions of submaximal intensity. It is proved that the manifestation of speed-strength endurance depends on hypoxic adaptability [20, 26].

At the same time, there are no research works that consider complex adaptive patterns in the process of karate training in conditions of normobaric hypoxia. Combining hypoxic effects with modification of physical loads allows to significantly improve the process of controlling the training of athletes in sports of submaximal intensity [3, 6, 8].

Adaptation mechanism to hypoxic hypercapnia is the complex integral reaction in which intrasystemic and intersystem rebuilding of the organism is manifested, which causes the special working capacity [9, 14, 18].

Studies [16, 28, 29] indicate that the achievement of high results in sports with a coordinated orientation of submaximal intensity depends on the rate of gas exchange in the lungs and the delivery of oxygen by blood to working muscles [15, 16, 17, 28].

In our studies, it was shown that in the initial stages of the hypoxic training of karate sportsmen aged 16-17, the increase in FeCO₂ in the exhaled air is a stimulator of lung ventilation, which is accomplished by increasing the respiratory rate with a slight decrease in the depth of breathing [21, 23, 24, 25, 28]. Later it was established that the achievement of the competitive activity of the karate sportsmen of 16-17 years of Indk₁ depends on the three main factors of hypoxic preparedness: the total respiration time in the closed space (T_(min²)); frequency of heart beats (HB), volume of the forced inhalation (FΒ_inhilation).

Conclusions
The analysis of the literature data made it possible to determine the general patterns of adaptation of the human body to the conditions of interval normobaric hypoxia, to determine which functional systems provide an adaptive effect and how the level of hypoxic adaptability contributes to a special sports performance.

An example of karate shows the important role of hypoxic stability in martial arts. The developed method of hypoxic training with the method of recurrent breathing allows us to determine the most important factors in raising the level of special physical fitness of karate sportsmen aged 16-17 and the most important factors of the oxygen transportation system in achieving the result.

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References


