Effectiveness of Physical Fitness Training of Athletes Based On Parameter Bayesian Estimation

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Abstract: In this paper, 64 national first-class athletes in speed skating and short-track speed skating were selected to participate in hypoxia training. In the study, athletes participated in a total of eight weeks of training, measured and analyzed the physiological indexes of athletes in normoxic environment and hypoxic environment. In the study, data analysis combined with machine learning was used to obtain the conversion formula of athletes' physiological indexes in hypoxia training and normoxia training. The experimental results show that the simulated hypoxia environment of 2300m is effective for athletes participating in both sports, in which the effect of short track speed skating is obvious, and the effect of speed skating is weak. Through the analysis, it is found that female athletes are more easily affected by hypoxia training. Relatively speaking, women who take part in the same hypoxia training get more benefits. The physiological indexes in normoxic environment and hypoxic environment are used in machine learning, and the transformation formulas of various physiological indexes under the environmental conditions in this study are successfully obtained. It is proved that the error between the hypoxia physiological index estimated by the transformation formula and the actual physiological index is small, which shows that the transformation formula is more accurate. This proves that hypoxia training can be estimated by means of machine learning to obtain more accurate data guidance, which has a strong practical significance for coaches to guide athletes' training.

Keywords: Hypoxia Training, Speed Skating, Short Track Speed Skating, Machine Learning, Physiological Index

1. Introduction

Since the 1970s, people have begun to study the influence and effect of hypoxia training on athletes \cite{1,2}. After decades of continuous development, the methods and systems of hypoxia training are becoming more and more perfect, and now hypoxia training widely used in the training of professional athletes. A large number of studies have pointed out that hypoxia training shows different effects in the face of different conditions and different objects. In Triathlon sports and swimming, hypoxia training has been proved to have a significant effect \cite{3,4}. The performance of the athletes who took part
in hypoxia training improved after hypoxia training. However, the advantages of hypoxia training may not necessarily be shown in other trainings. Some studies have pointed out that short-term intermittent hypoxia training will not bring significant benefits to anaerobic athletes \[5\]. In the study of Colleen G. Julian et al, short-term intermittent hypoxia training can not improve the performance of excellent middle-and long-distance runners \[6\]. The relative changes of some physiological indexes of athletes (such as red blood cells, hemoglobin, etc.) is an important reference to reflect the effect of hypoxia training. For endurance training and non-endurance training under the same conditions, the changes of physiological indexes of athletes are not the same \[7\]. Therefore, the effects of hypoxia training under different hypoxia conditions and different sports on the training effect of athletes need to be further studied.

2. Experimental Theory and Method

2.1 Experimental Theory

2.1.1 Living high and training low. Hypoxia training will make the body form a series of adaptive compensatory response and stress response, which can improve the physiological index of athletes, so that athletes have better performance in training. The dual stimulation of hypoxia and exercise load will aggravate the response. However, this reaction also has some disadvantages. In order to avoid its negative effects on body function and make effective use of hypoxia stimulation in altitude training to improve the advantage of oxygen transport and utilization, the training method of living high and training low was adopted. Living high and training low usually means that athletes live in anoxic environment, while training is in normal oxygen concentration environment. This method solves the contradiction between exercise load and hypoxia load in traditional altitude training, and weakens some negative effects of persistent hypoxia on athletes.

2.1.2 Determination of physiological indexes. In this paper, several physiological indexes related to oxygen transport system were selected to test. The oxygen transport system of the human body is mainly based on blood. In the detection of blood routine indexes, Red blood cell (RBC), Hemoglobin (Hb) and hematocrit (Hct) are important indicators to reflect the ability of human oxygen transport. These indicators are more sensitive to the changes of external oxygen concentration, and it is easier to reflect the effect of hypoxia training. Blood oxygen saturation (SaO\(_2\)) is an important index to reflect the oxygen content in human body. When the external oxygen concentration decreases, the oxygen content of unit hemoglobin in red blood cells will decrease, and the blood oxygen saturation will decrease accordingly, which will stimulate the body to produce erythropoietin. Erythropoietin will promote the production of red blood cells, to achieve the purpose of increasing the content of red blood cells, in order to ensure that the human body will not be deprived of oxygen. Therefore, after the human body has entered a state of hypoxia, in addition to the above indicators will change, the number of immatured blood cells in the blood will also increase. Reticulocyte (Rtc) is not yet fully matured red blood cells, its value in the surrounding blood can reflect the bone marrow red blood cell production function, reflect the red blood cell formation rate.

2.1.3 Feature extraction by machine learning. In the motion data analysis, the conventional data processing is based on statistical analysis, so that the general trend can be obtained, but it is not accurate. Using machine learning to extract the target characteristics, and then synthesizing a change curve, we can more accurately estimate the impact of hypoxia training on athletes. The core idea of this feature extraction is to minimize the error of the parameters to be estimated by the least square method, and to find the optimal weight by setting the weight model of null value and using gradient update.

2.2 Experimental Method
The study selected a total of 64 national first-class athletes from short-track speed skating and speed skating in Jilin Province, China. The same number of athletes participated in the study in both sports. All athletes are in good health, have no respiratory system, cardiovascular system, endocrine system and other diseases and regularly participate in the annual training. All athletes signed the informed consent form for the experiment. All athletes are in the adjustment period and have no competition tasks.

In the study, athletes were divided into four groups according to gender and type of sports. The experiment lasted for eight weeks, the first week and the last three weeks were routine training, and the second week to the fifth week were in the hypoxia training state of living high and training low (HiLo). In the experiment, in order to eliminate the interference of factors other than hypoxia, the athletes received a unified living arrangement (including training, rest, diet, etc.) Before each measurement, under the condition of keeping the athletes awake, lie still on the bed for three minutes, and each measurement time is maintained at 7 o'clock in the morning (±15 minutes).

First of all, the measurement results are analyzed by the method of mathematical statistics, and the statistical results are shown in Table 1 and Table 2. The transformation formulas of the corresponding physiological indexes are obtained by machine learning processing. First of all, the data of statistical analysis are preprocessed, the distribution of physiological indexes of human body accords with normal distribution, and the principle of mathematical statistics used to expand the data.

\[
\begin{align*}
\text{Model:} & \quad Y_i = \beta_0 + \beta_1X_i + \beta_2X_2 + \ldots + \beta_pX_p \\
\text{Where the coefficient weight vector is:} & \quad \beta = [\beta_0, \beta_1, \beta_2, \ldots, \beta_p] \\
\text{Note that the maximum loss between the model and the actual value is:} & \quad \min \sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2 \\
\text{So the initial value of the weight vector is:} & \quad \hat{\beta} = (X'X)^{-1}X'Y
\end{align*}
\]

After regularizing the weight vector, after dozens of rounds of iteration through the automatic gradient, the weight vector gradually converges to less than 1% of the estimation error to stop the iteration. The weight obtained in the process of gradient iteration will be over fitted, and the phenomenon of gradient explosion may occur in the process of gradient iteration. Therefore, the dimension of the initial weight is artificially limited in the study. Finally, the transformation formula of hypoxia training was obtained. By inputting the values of physiological indexes of athletes training in normal environment, the transformation for mulacan output the estimated values of physiological indexes of hypoxia training of athletes in the current hypoxia environment.

3. Experimental Results

Table 1 shows the statistical results of short-track speed skaters during hypoxia training, and Table 2 shows the statistical results of speed skaters during hypoxia training. This study mainly counted the average value of physiological indexes of each group of athletes in the whole process of hypoxia training and the average improvement rate of physiological indexes after hypoxia training. The improvement rate of hypoxia training refers to the ratio of the average change rate of physiological indexes of each athlete after hypoxia training to that of normal training, which reflects the influence of hypoxia training on physiological indexes. The promotion rate shown in the table is the average of the promotion rate of all athletes in the group.
Table 1. Statistical results of short track speed skaters during hypoxia training

| Index | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Promotion rate |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|----------------|
| Man   |        |        |        |        |        |        |        |        |                |
| RBC(g/ml) | 5.24  | 5.19  | 5.12  | 5.25  | 5.47  | 5.40  | 5.55  | 5.29  | 0.063          |
| Hb(g/dl)  | 15.43 | 15.49 | 15.29 | 15.91 | 16.21 | 16.03 | 16.47 | 15.46 | 0.058          |
| Hct(%)   | 45.34 | 43.21 | 42.64 | 44.49 | 45.84 | 45.06 | 47.23 | 43.64 | 0.046          |
| Rtc      | 0.644 | 0.819 | 0.827 | 0.810 | 0.798 | 0.801 | 0.665 | 0.231 |                |
| SaO2(%)  | 96.2  | 93.0  | 92.4  | 92.5  | 92.5  | 93.8  | 94.2  | 95.6  | -0.027         |
| Woman   |        |        |        |        |        |        |        |        |                |
| RBC(g/ml) | 4.60  | 4.98  | 4.98  | 5.04  | 5.09  | 4.70  | 5.01  | 4.89  | 0.112          |
| Hb(g/dl)  | 13.61 | 14.04 | 14.82 | 15.19 | 14.89 | 14.28 | 14.79 | 14.36 | 0.097          |
| Hct(%)   | 38.83 | 40.73 | 39.49 | 41.95 | 40.56 | 39.75 | 42.81 | 42.55 | 0.065          |
| Rtc      | 0.625 | 0.842 | 0.841 | 0.832 | 0.765 | 0.721 | 0.702 | 0.243 |                |
| SaO2(%)  | 96.7  | 92.5  | 91.8  | 91.8  | 91.5  | 92.6  | 93.8  | 95.4  | -0.035         |

Table 2. Statistical results obtained from measurements during hypoxic training of speed skaters

| Index | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Promotion rate |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|----------------|
| Man   |        |        |        |        |        |        |        |        |                |
| RBC(g/ml) | 5.24  | 5.43  | 5.27  | 5.35  | 4.98  | 4.99  | 5.06  | 5.24  | 0.024          |
| Hb(g/dl)  | 15.69 | 16.27 | 15.77 | 16.00 | 15.74 | 14.91 | 15.14 | 16.28 | 0.018          |
| Hct(%)   | 44.07 | 45.24 | 43.99 | 44.99 | 41.89 | 42.83 | 43.26 | 46.56 | 0.014          |
| Rtc      | 0.691 | 0.721 | 0.732 | 0.756 | 0.758 | 0.742 | 0.731 | 0.722 | 0.041          |
| SaO2(%)  | 98.25 | 92.95 | 93.07 | 93.65 | 93.92 | 94.32 | 95.7  | 95.9  | -0.032         |
| Woman   |        |        |        |        |        |        |        |        |                |
| RBC(g/ml) | 4.26  | 4.71  | 4.62  | 4.36  | 4.52  | 4.31  | 4.62  | 4.70  | 0.094          |
| Hb(g/dl)  | 12.37 | 13.84 | 13.60 | 12.83 | 13.33 | 13.03 | 13.13 | 13.86 | 0.093          |
| Hct(%)   | 35.93 | 39.46 | 39.09 | 37.23 | 38.23 | 37.39 | 38.27 | 39.97 | 0.051          |
| Rtc      | 0.901 | 0.982 | 0.921 | 0.958 | 0.981 | 0.985 | 0.942 | 0.931 | 0.064          |
| SaO2(%)  | 98.2  | 92.9  | 93.9  | 94.5  | 94.5  | 95.1  | 96.3  | 97.1  | -0.043         |

Through many iterations of machine learning, the final optimization result is obtained. Some of the results are presented in the form of mathematical expressions after simplification. Formula (6) ~ (10) is the red blood cell transformation formula of men in short track speed skating obtained by machine learning. Among them, x is the physiological index of athletes during normal training, k is the bias of machine learning, and the weight items are omitted within the allowable range of error, and the maximum number of weight items is no more than 5.
4. Discussion and Analysis
The experimental results show that hypoxia training has an effect on the physiological indexes of skaters, but the degree of influence is different for different sports. Due to the different training plans of short-track speed skating and speed skating, the changes of physiological indexes are different. Relatively speaking, under the same hypoxia training conditions, the physiological index improvement rate of oxygen transport system of short-track speed skaters under hypoxia training is higher, while that of short-track speed skaters is lower. The physiological indexes of both sports have been improved, which can prove that hypoxia training does have some influence on the physiological indexes of athletes in these two kinds of sports. Some studies have shown that a decrease in oxygen saturation can lead to an increase in hemoglobin to offset its negative effects. The main function of hemoglobin is to transport oxygen and affect the operation of the body. Under the high pressure of oxygen, oxygen in the lung tissue combines with hemoglobin to form oxyhemoglobin. When the oxygen concentration in the environment decreases, the relative oxygen uptake of the body decreases, resulting in a decrease in the oxygen binding of hemoglobin. In order to adapt to this situation, the body will increase the level of hemoglobin to increase the binding and release of oxygen. There is hemoglobin in red blood cells, and the increase of hemoglobin will inevitably lead to erythrocytosis. The increase of erythrocytes is related to erythropoietin. The acceleration of red blood cell production means the corresponding increase of reticulocyte production. An increase in the total number of red blood cells will lead to an increase in hematocrit. This shows that the oxygen transport capacity of athletes has been improved after hypoxia training, which is conducive to the improvement of athletes’ performance. According to tables 1 and 2, the changes of physiological indexes after hypoxia training are consistent with the expected changes.

By comparison, it is found that hypoxia training has a greater impact on female athletes. In the study, although the changes of physiological indexes of the two kinds of exercise are different, the improvement rate of physiological indexes of women is generally higher than that of men in the same kind of exercise. This shows that women are more sensitive to hypoxia training, in other words, women are more likely to be affected by hypoxia training, and women may get more benefits from hypoxia training. But relatively speaking, this shows that men are less likely to be affected by changes in external oxygen concentrations.

The indexes of hypoxia training are analyzed by machine learning, and the physiological index transformation formulas of normal training and hypoxia training are obtained. After the test of the test data, the accuracy of the transformation formula is more accurate than the traditional statistical analysis method. The error of the prediction is no more than 3%. The researchers believe that there is a certain dependence between the changes of athletes’ physiological indexes and oxygen concentration in hypoxia training, and the traditional statistical analysis methods can only get its approximate change trend, but can not accurately estimate the range of physiological indicators after training. Machine learning can use machine language to enlarge the features in the data, and then provide a transformation relationship through the weight vector. This is enough to prove that in hypoxic exercise training, handing over the work of data analysis to machine learning will be a more effective strategy for data processing, and machines will provide a more accurate reference value more efficiently.

5. Conclusion
The research shows that hypoxia training can improve the physiological indexes of both short-track speed skating and speed skating athletes. For two different sports, even if the training conditions and environment are the same, the training results are indeed different. The researchers believe that hypoxia training has different effects on athletes in different sports. Comparatively speaking, female athletes are more sensitive to hypoxia environment, and the more benefits they get from participating in hypoxia training. In the study, the transformation formula of hypoxia training is successfully obtained by using the method of machine learning, and its prediction accuracy is higher than that of traditional statistical analysis. This shows that hypoxia training can be combined with machine learning to obtain more accurate results, in order to achieve the purpose of better guiding sports training.

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