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Research Article

Multimedia Recognition and Monitoring of Respiration and Heart Rate VO_2 Max in Exercise Training Based on Regression Equation

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As an important basis for improving physical fitness and promoting health, the author proposes a research on the identification and monitoring of VO_2 max in exercise training based on regression equations. Six female cyclists in province A were used as the experimental subjects. The experimental period was 4 weeks, and the training content was carried out by the coaches according to the training plan. The coefficients of the resulting equations were not significant by a univariate regression analysis of heart rate at LT and V_0O. When heart rate is used as the dependent variable, Y represents LT, X represents VT, and heart rate is the independent variable, and unitary regression analysis is performed to obtain the following equation: VT-LT heart rate regression analysis before training: $Y = 200.828–0.240X$ $P = 0.391 > 0.05$; training post-VT-LT heart rate regression analysis: $Y = 239.445–0.469X$ $P = 0.073 > 0.05$; VT-LT heart rate comprehensive regression analysis: $Y = 218.120–0.343X$ $P = 0.043 > 0.05$, the coefficients are significantly different, and the equation is reliable.

1. Introduction

With the improvement of social living standards, most social groups spend their time on making money, thus lack of physical exercise, especially young people, because of lack of exercise, or not enough time spent on exercise, the body has been in an unhealthy state [1]. For young people, regardless of whether it is physical or psychological health, it is particularly important, their physical fitness is also closely related to the development of society. The main test target of cardiopulmonary function is the maximum oxygen uptake. The maximum oxygen uptake refers to the amount of oxygen that the human body can absorb per minute when the cardiopulmonary capacity and the ability of the muscles to use oxygen reach the maximum level of the human body with a large number of muscle groups participating in the process of long-lasting strenuous exercise [2]. Maximal oxygen uptake can show the body's ability to absorb oxygen, transport oxygen, and the extent to which it uses oxygen, so to a certain extent, it can be used as a reference basis for judging individual aerobic exercise activities. A test of the maximum oxygen uptake of children, in order to evaluate children's cardiopulmonary function, researching the correlation between the two, found that there is a clear correlation between the two and also uses it to judge the coordination of children; related investigations found that, using the maximum oxygen uptake to judge the endurance of karate players in advance, it has practical significance [3]. Through the incremental load test program, measured resting heart rate, maximum heart rate, and exhausted heart rate, on the basis of maximum load and maximum oxygen uptake, understand the basic information of the subject, such as test subjects' age, gender, height, weight, and other morphological indicators, and establish these indicators as independent variables; the maximum oxygen uptake is the dependent variable, the optimal regression equation is for inferring the maximum oxygen uptake of adolescents, in order to establish a scientific, simple, and easy method to evaluate the heart and lung function of adolescents, provide a basis, and provide a theoretical basis for the physical quality assessment and scientific fitness of adolescents, as shown in Figure 1; it is the heart rate state recognition

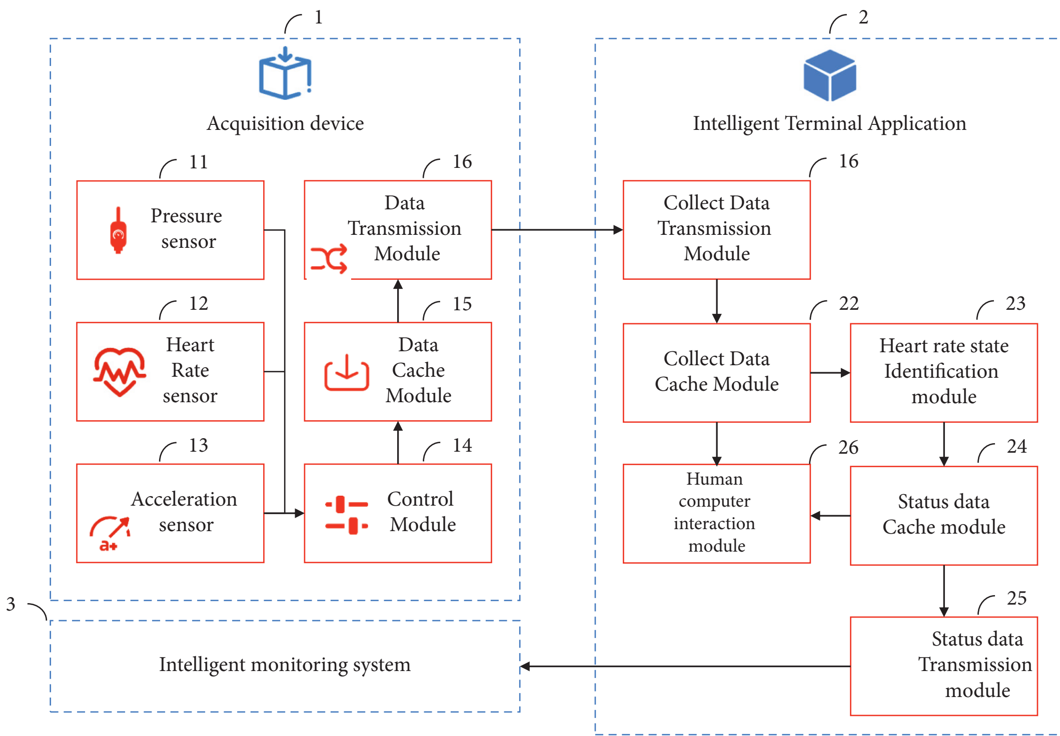

Figure 1: Heart rate status recognition method and process.

method and process [4]. Aerobic endurance is the quality base for cyclists to achieve excellent results. Monitoring the changes of some aerobic endurance indicators of cyclists can effectively guide and supervise training. There are many indicators of aerobic endurance, such as lactate threshold (LT), ventilation threshold (VT), and maximal oxygen uptake (VO_{2max}). Heart rate (HR) is an effective indicator to monitor exercise intensity. By establishing HR-LT (VT) control intensity model, training intensity can be effectively controlled and scientifically guided.

2. Literature Review

In response to this research question, Kam et al. studied on the regression equation of inferred maximum oxygen uptake, through a simple test, determined some relevant indicators of the subject, and speculated the regression equation model that can directly calculate the maximum oxygen uptake; the method is simple and easy to implement [5]. Zhang et al. studied the method of inferring the maximum oxygen uptake of the middle-aged and elderly people. In the study, the middle-aged and elderly people were used as the research objects, and the exercise method and the incremental method were used to conduct experiments. The results of the load exercise were compared and analyzed, some relevant indicators were measured, and a hypothetical middle-aged and elderly population was established to obtain the regression equation of the maximum oxygen uptake [6]. Liu et al. aimed at college students and adults, also used a form of exercise, and discussed the method of inferring the maximum oxygen uptake of this group of people; the regression equation model was established [7]. Qi et al., for the method of measuring the cardiorespiratory ability of junior high school students aged 13–15, researched through some morphological and physiological indicators and calculated the regression equation model suitable for them [8]. Huang et al. studied the evaluation method of maximum oxygen uptake; the target population is active military personnel [9]. Chen et al. studied the monogram method and used pulse to calculate maximum oxygen uptake, and it is not necessarily very scientific in step experiments and the subject's psychological factors; it will also have a certain impact on the test results [10]. Xie et al. used different methods to test and compare the maximum oxygen uptake and related indicators of young athletes, college students, and some professionals, so as to provide some basis for predicting athletes' personal sports potential and physical fitness monitoring [11]. Guo et al. divided the exercise load intensity, mainly based on several inflection points such as ventilation threshold and blood lactic acid content, as a boundary [12]. Zhang and Li proved through experiments that the ventilation threshold and lactate threshold decrease with the decrease of oxygen partial pressure; there is a phenomenon of simultaneous decrease, but the magnitude of the reduction is not the same [13]. The experiment of Ahmed et al. found that ventilation threshold is highly correlated with lactate anaerobic threshold, changes in lactate cause nonlinear changes in ventilation threshold [14]. Based on this study, the maximum oxygen intake of 40~ and 49 years old was established by the 1 km walking test, exploring the feasibility of walking exercise as an indirect test of adolescent heart and lung function (VO2max) and performing another 1 km walking test on the heart rate and physical fitness parameters as the independent variables, and the corresponding heart rate value and walking time were averaged for calculation. The relevant regression equations are obtained. The regression equation with cross-validation shows a correlation statistic for measured and inferred values for maximum oxygen intake of RLOOCV = 01826 and SEELOOCV = 01378 (L/min). Using a 1 km walking test and using this equation can effectively speculate on the maximum oxygen intake of 40~ in healthy adults aged 49.

3. Methods

3.1. Research Objects. There are 6 female cyclists from Province A, with similar professional level, age (21.50 ± 2.99) years old, height (170.50 ± 1.89) cm, weight (60.58 ± 3.96) kg, body fat percentage (23.60 ± 2.37)%, and BMI (20.83 ± 1.20) kg/m^2. In good health, there is no significant difference in cardiopulmonary function.

A CNNs model can be expressed as follows:

$$cx_{ij} = -\frac{1}{R}x_{ij} + \sum_{kl\in Nij(r)} a_{kl}y_{kl} + \sum_{kl\in Nij(r)} b_{kl}u_{kl} + z_{ij}, \tag{1}$$

$$y_{ij} = f\left(x_{ij}\right) = \frac{1}{2}\left(\left|x_{ij}+1\right| - \left|x_{ij}+1\right|\right), i = 1, 2, \ldots, M, \quad j = 1, 2, \ldots, N. \tag{2}$$

Rearrange these 3 templates into a one-dimensional array with 19 real numbers, which is called a CNNs gene template and denoted by G as the following equation:

$$G = [\, z \;\; b_9 b_8 \ldots b_1 \;\; a_9 a_8 \ldots a_1 \,]. \tag{3}$$

Equation (1) can be written in the form of a matrix. For the state vector equation of CNNs composed of n neurons, see the following equation:

$$CX = -\frac{1}{R}X + A * Y + B * U + Z. \tag{4}$$

Let $C = 1$, $R = 1$ in formula (1), then formula (1) becomes the following standard CNNs equation, as shown in the following formulae:

$$\dot{x}_{ij} = x_{ij} + \sum_{kl\in Nij(r)} akl f\left(x_{kl}\right) + \sum_{kl\in Nij(r)} b_{kl}u_{kl} + z_{ij}, \tag{5}$$

$$y_{ij} = f\left(x_{ij}\right) = \frac{1}{2}\left(\left|x_{ij}+1\right| - \left|x_{ij}-1\right|\right), i = 1, 2, \ldots M, \quad j = 1, 2, \ldots, N. \tag{6}$$

Assuming that the 3x 4CNNs have a fixed boundary condition, see the following equations:

$$x_{i^* j^*} = 0, \tag{7}$$

$$u_{i^* j^*} = 0. \tag{8}$$

In the formula, (i^*, j^*) represents the position of the border cell, that is, see formula (9):

$$\left(i^*, j^*\right) \in \{(1,1), (1,2), (1,3), (1,4), (2,1), (2,4), (3,1), (3,2), (3,3), (3,4)\}. \tag{9}$$

3.2. Research Methods. The probationary period is 4 weeks and the content of the training is performed by the coach according to the training plan. One day before the start of the training cycle and one day after the end of the fourth week, the patient underwent aerobic capacity testing and blood lactate concentration was checked by grade blood pressure. Both tests were performed between 08:00 and 11:00 in the morning.

Aerobic endurance test method: in the laboratory, after asking the subject to sit quietly on a Monark 839 power bicycle for 5 minutes, measure his oxygen uptake (VO_2), ventilation (VE), heart rate (HR), and other indicators at rest, then the subjects used Bruce's method; peddle your bicycle until you are exhausted. When doing incremental load exercises, the subject wears a breathing mask to exercise, simultaneously measure various indicators of gas metabolism, that is, VO_2, VE, carbon dioxide emissions per minute (VCO_2), and respiratory quotient (R). Before the experiment, the 2900 gas analyzer was calibrated with standard gas [15].

$VO_{2\,\max}$'s judgment can be determined when any 3 of the following 4 situations occur at the same time: (1) VO_2 no longer increases and a platform appears; (2) R is greater than 1.2; (3) HR is greater than 180 times/min; (4) the test of BLa concentration greater than 9 mmol/LLT adopts a graded load test scheme, the test index is blood lactic acid (BLa), take a blood sample (0.02 mL) from the fingertips, and immediately use the blood lactic acid automatic analyzer (1500 Model A Yellow Springs Instrument Co., USA) to analyze and determine the blood lactic acid concentration. LT uses the strength when the blood lactic acid reaches 4.0 mmol/L, the method of expressing the lactate threshold; by testing the blood lactate concentration, find out the heart rate at the lactate threshold [16].

Ventilation threshold (VT) judgment criteria is as follows: corresponding to the exercise time, the ventilation volume (VE) starts to increase nonlinearly; corresponding to the exercise time, carbon dioxide emissions (VCO_2) show a nonlinear rise. Physical training for standard exercise intensity: the intensity is mainly controlled by the heart rate, and other training is carried out normally [17].

3.3. Common Methods for Estimating Maximum Oxygen Uptake in Power Vehicles. The direct test method is generally used in the laboratory, direct testing by gas analyzer; let the subject in the power car, and do progressively increasing load exercises, so as to measure its oxygen uptake, and it is easier to get some index data such as heart rate [18]. Athletes with training experience: it is suitable to use the direct measurement method to test the maximum oxygen uptake, because of its reliable data and good repeatability, it can accurately and objectively assess the aerobic capacity of athletes [19]. People who have no training experience are also more suitable, because the direct test of the power car is not burdensome, the usual cycling is relatively close; it is easier for subjects to accept, so that they can complete the test better; there is a more accurate evaluation of the subjects' cardiorespiratory endurance level [20].

3.4. Data Statistics and Analysis. All data are statistically processed by SPSS15.0 statistical software package, expressed as mean ± standard deviation ($x \pm s$); use paired t test and unary regression method (full regression) for analysis; $P < 0.05$ is the difference, which is significant [21].

4. Results and Analysis

4.1. Changes in VO_2, VE, and Heart Rate after Incremental Exercise. As shown in Figures 2–4, VO_2, VE, and heart rate in two incremental exercises gradually increase with time, there is an inflection point at 12~13 min, VO_2 and VE changes from a gentle increase to a sharp increase, and heart rate changes tend to be flat. After training, VO_2, VE, and heart rate are slightly higher than before training, but the paired t test showed that the difference was not significant ($P > 0.05$) [22].

4.2. Changes in the Maximum Value during Incremental Exercise. The absolute value of the maximum oxygen uptake before and after training, the relative value of the maximum oxygen uptake, and VE_{max}, HR_{max}, and exhaustion time change little; the difference was not significant ($P > 0.05$), as shown in Table 1.

4.3. Changes in the Ventilatory Threshold and Maximum Oxygen Uptake during Incremental Load Exercise. After training, the relative values of ventilation threshold, heart rate, and oxygen uptake are compared with those before training, VO_2, VE, and VCO_2 increased slightly, but the difference was not significant; compared with before training, the respiratory quotient (R) was significantly higher ($P < 0.05$). After training, the maximum oxygen uptake appears to be delayed by about 1 min, the difference is significant ($P < 0.05$), and the heart rate at the time of maximal oxygen uptake drops significantly ($P < 0.05$), while other indicators remained unchanged or slightly increased; the difference was not significant [23]. During VT before

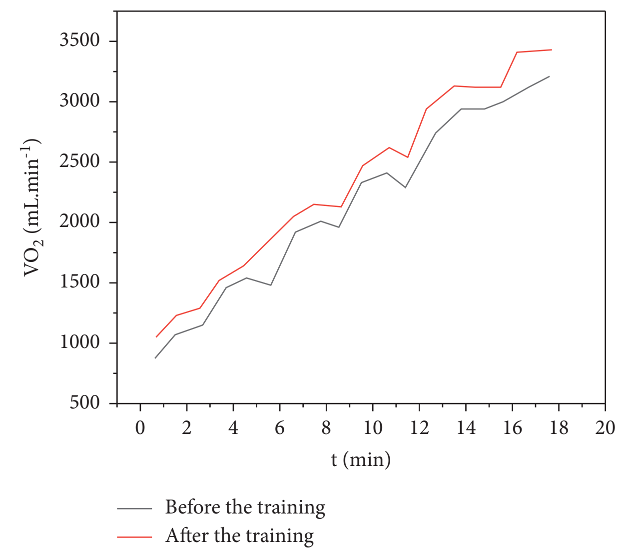

Figure 2: VO_2-t curve during incremental load exercise.

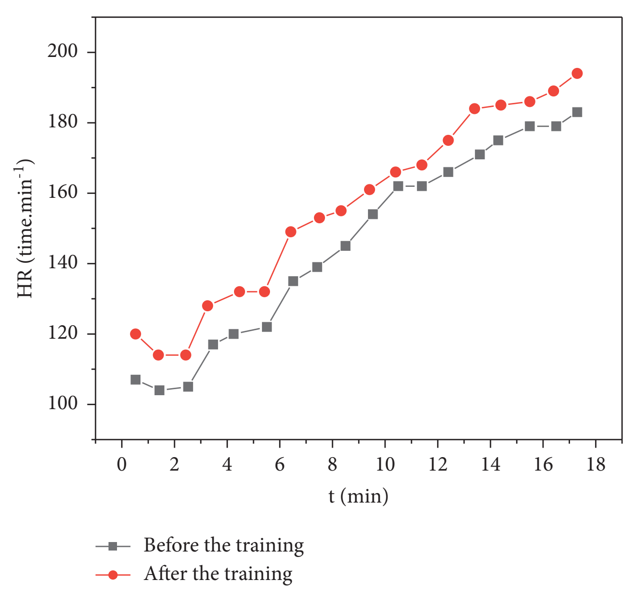

Figure 3: HR-t curve during incremental load exercise.

training, the percentages of the maximum value of each index of VO_2, VE, and HR, respectively, are (79.32 ± 3.18)%, (58.89 ± 6.99)% and (88.99 ± 3.89)%; after training, they were (80.21 ± 7.59)%, (58.98 ± 6.98)%, and (90.26 ± 3.17)%; there was no significant difference ($P > 0.05$), as shown in Tables 2–4.

4.4. LT, VT, and $VO_{2\,max}$ Heart Rate and Its Correlation and Regression Analysis. The average heart rate during VT before training is (168.5 ± 6.11) beats/min; after training, it is (168.99 ± 5.49) beats/min, the correlation coefficient is 0.879 ($P < 0.05$), and the heart rate at LT before training is (159.89 ± 3.34) beats/min; after training, it was (161 ± 3.44) times/min, and the correlation coefficient was 0.949 ($P < 0.05$). The $VO_{2\,max}$ heart rate before and after training

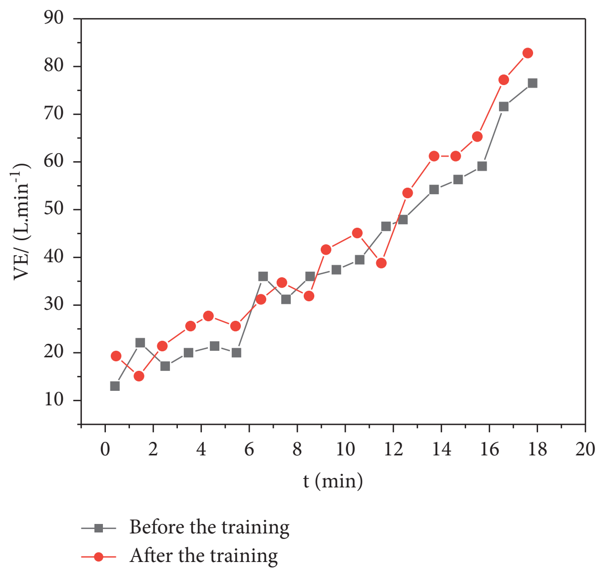

FIGURE 4: VE-t curve during incremental load exercise.

TABLE 1: Test results of the maximum value of related indexes after increasing load exercise.

Testing time	$VO_{2\,max}$	V	VE_{max}	HR_{max}	$t_{exhaustion}$/min
Before training	33.61.89 ± 276.74	55.75 ± 5.27	115.53 ± 14.39	187.42 ± 5.64	17.56 ± 1.31
After training	3469.85 ± 275.98	57.34 ± 5.68	113.75 ± 11.45	188.48 ± 5.41	17.98 ± 1.32

TABLE 2: Changes in ventilation threshold and maximum oxygen uptake $t_{exhaustion}$/min, HR, and HR_{max}/% during incremental load exercise.

Testing time	$t_{exhaustion}$/min		HR		HR_{max}/%	
	Ventilatory threshold	At maximal oxygen uptake	Ventilatory threshold	At maximal oxygen uptake	Ventilatory threshold	At maximal oxygen uptake
Before training	12.69 ± 0.69	16.10 ± 0.65	169.49 ± 6.01	186.77 ± 7.43	88.99 ± 3.89	
After training	12.76 ± 0.43	17.01 ± 2.21	169.43 ± 5.35	183.1 ± 6.13	90.26 ± 3.17	

TABLE 3: Changes in ventilatory threshold and maximal oxygen uptake during increased load exercise, VE, VE_{max}/%, and $VO_{2\,max}$

Testing time	VE		VE_{max}/%		$VO_{2\,max}$	
	Ventilatory threshold	At maximal oxygen uptake	Ventilatory threshold	At maximal oxygen uptake	Ventilatory threshold	At maximal oxygen uptake
Before training	65.49 ± 7.29	105.89 ± 13.99	58.89 ± 6.99		2663.97 ± 220.97	3362.71 ± 267.57
After training	67.99 ± 10.31	110.43 ± 14.98	58.98 ± 6.98		2775.76 ± 311.89	3469.38 ± 275.98

TABLE 4: Changes in ventilation threshold and maximum oxygen uptake V^2, $VO_{2\,max}$/%, and $VCO_{2\,max}$ during incremental load exercise.

Testing time	V^2		$VO_{2\,max}$/%		$VCO_{2\,max}$	
	Ventilatory threshold	At maximal oxygen uptake	Ventilatory threshold	At maximal oxygen uptake	Ventilatory threshold	At maximal oxygen uptake
Before training	44.23 ± 4.87	55.75 ± 4.91	79.32 ± 3.18		2419.27 ± 202.67	3556.84 ± 320.42
After training	44.10 ± 3.95	57.43 ± 5.68	80.21 ± 7.59		2426.99 ± 240.61	3680.79 ± 343.62

was (185.65 ± 7.54) beats/min and (182.99 ± 6.32) beats/min; the correlation coefficient was 0.858 ($P < 0.05$) [24]. There was no significant difference between VT and LT heart rate before and after training ($P > 0.05$); the correlation coefficient between the two total VT and LT heart rate is −0.582 ($P < 0.05$) [25].

Through the unary regression analysis of heart rate at LT and V0O, the coefficients of the equation are not significant [26]. Let Y represent LT when the heart rate is the dependent variable, when X represents VT, the heart rate is the independent variable, and the unitary regression analysis is performed, obtaining the following equation:

VT-LT heart rate regression analysis before training: $Y = 200.828–0.240X,\ P = 0.391 > 0.05$

Regression analysis of VT-LT heart rate after training: $Y = 239.445–0.469X,\ P = 0.073 > 0.05$

Comprehensive regression analysis of VT-LT heart rate: $Y = 218.120–0.343X,\ P = 0.043 < 0.05$, the coefficient difference is significant, and the equation is reliable [27]

5. Conclusion

The author proposes a study to determine and control the VO2 max of breathing and heart rate exercises based on the regression equation of the ventilation threshold and the heart rate regression equation for better use in practice. Experimental results show that the two-threshold heart rate regression analysis is performed alone before or after exercise, and the P value of the equation is greater than 0.05. The two data are mixed together and perform the same regression analysis. The equation is Y (LT heart rate) = 218.120–0.343X (VT heart rate), $P = 0.043 < 0.05$, with significant differences, and the equation is reliable. Due to the limited duration and scope of the study, the authors limited the scope to 4 female cyclists in Aimag A for 4 weeks, thereby improving the rationale and benefits of the aerobic hypothesis equation. Suggestions for future research directions: the team heart rate monitor can be used to monitor the heart rate of the training athletes during the training camp. Analyzing the monitoring results can help coaches to timely and accurately understand the adaptation of athletes to training intensity, master the cardiopulmonary function of each athlete, provide coaches with a series of data indicators, and help coaches formulate training more scientifically and plan and coach athletic training for youth athletes.

Data Availability

The data used to support the findings of this study are available from the author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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