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Numerical simulation study on the improvement of athletic ability of athletes by load regulation in aerobics training

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Abstract Exercise load is a quantitative physiological index and training intensity index that athletes and coaches are extremely concerned about. In order to obtain valuable potential information from a large amount of random exercise load data, with the assistance of data mining technology, a training load monitoring method based on aerobics athletes is proposed, which utilizes the association rule method to mine valuable information for predicting the amount of human exercise. After that, a kinetic model of the sports training function monitoring system with mutual feedback relationship among athlete's function, training and recovery is constructed to provide rationalized suggestions for training load regulation of aerobics athletes. Numerical simulation results show that the system in this paper is more suitable for data mining of athletic biochemical indexes of aerobics athletes. The numerical simulation results of aerobics training load regulation show that with the gradual increase of the training load level and training movement intensity regulation factor of aerobics athletes, their recovery cycle optimization factor will gradually decrease, and when each regulation factor is increased by 20%, the athlete's athletic ability level can be increased by up to 7.87% compared with the original. In addition, the regulation of movement complexity shows that the training load has a time lag effect with the improvement of athletic ability level.

Index Terms Data mining, association rules, training load monitoring, system dynamics, aerobics

I. Introduction

With the gradual deepening of the market economic environment and the continuous improvement of the difficulty of special techniques, aerobics has gradually derived from competitive aerobics for the purpose of training for competition on the basis of mass fitness [1]. With the successive establishment of the international authoritative organizations International Gymnastics Federation (FIG), International Aerobics Federation (IAF) and International Federation of Aerobics Champions (ANAC), and the introduction and continuous improvement of the international competition rules, competitive aerobics has gradually formed a competitive program with unique characteristics based on the fitness function with the ultimate purpose of obtaining excellent competition results [2]-[5]. In the 2013-2016 version of the rules of competitive aerobics, the International Federation of Physical Education (FEI) defines competitive aerobics as an athletic program that is able to demonstrate the ability to perform continuous, complex, and high-intensity sets of movements accompanied by music [6]. Sets are composed of a cross-mix of seven basic steps combined with difficult technical maneuvers to reflect the athlete's competitive ability [7].

Physical function is an important part of the athlete's physical fitness and forms the basis of the athlete's athletic ability, which is directly proportional to the quality of the athlete's skill completion [8]. Functional state of good and bad directly affects the athletes in training and competition in the physical and skill play, good physical function can make the athletes have sufficient physical reserves, body fatigue phenomenon delayed appearance, is the game athletes successfully use technology, tactics of the guarantee [9]-[11]. As early as in the 1950s, Chinese sports researchers have been deeply involved in the first line of competitive sports programs, engaged in the evaluation and research of athletes' physical function [12]. In the early days, physical function research was mainly conducted through the physiological and biochemical indexes in urine and blood, combined with the Ledunov joint function test and the Harvard step test for function assessment [13]. By the 1970s, many Western countries began to conduct more comprehensive and systematic monitoring of the condition of the level of physical ability of professional athletes, and established assessment standards appropriate to the sports program, which were continuously reformed and developed in the course of the subsequent training practice to help coaches improve the athletes' competitive level [14], [15].

Through the study of literature related to aerobics function, Shen, M et al [16] found that functional strength training can improve the athletic stability and flexibility of aerobics athletes, as well as enhance the overall strength, motor coordination, control and stability of aerobics athletes, thus effectively preventing athletic injuries. Bari, M. A et al [17] found that aerobic aerobics training was able to have a significant positive effect on physical functions such as certain liver function indicators in athletes, effectively reducing bilirubin and globulin levels. Campbell, A et al [18] found that long-term aerobic aerobics exercise attenuates endothelial vascular function that declines with age. Mckendry, J et al [19] found that long-term endurance and strength training maintained physical function, muscle strength and body composition in older athletes compared to age-matched untrained controls. Most of the current experts and scholars on the physical function of aerobics athletes have certain limitations, from the macro perspective of physical fitness to the study of physical fitness, the study of physical fitness is the main focus of the study, the research involving physical function is very limited in length.

The study of exercise load and its broad definition have varied over time and in different countries, and have not yet been fully harmonized and summarized. Gabbett, T. J et al [20] stated that higher training loads can be protective against injury, but excessive training loads can also lead to a large percentage of non-contact soft tissue injuries. Fitzpatrick, J. F et al [21] proposed an individualized approach to monitoring training loads, which in applying training stimuli by means of physical exercises, such that the organism produces functional changes in the physiology accompanying a certain load stimulus. Foster, C et al [22] went from early observation-based approaches to more recent approaches focusing on internal training loads and the use of technologies such as heart rate monitors and power meters, with heart rate being one of the most commonly used, physiological indicators of the intensity of training loads. Gabbett, T. J et al [23] stated that rapid increases in training and competition loads, as well as low chronic loads are associated with greater risk of injury, while appropriate training programs can reduce the risk of injury in athletes.

In this paper, we first design the association rule mining algorithm used to collect the sports load monitoring information, and then design the microcontroller, data storage module, wireless communication module to constitute the sports load information collection model to complete the collection of aerobics athletes' training load data and realize the real-time monitoring of athletes' sports load status. After that, system dynamics is utilized to combine the scientific theory of training load regulation of aerobics athletes with computer simulation to obtain the relationship between training load regulation and athletes' athletic ability. Then, taking training and recovery as the system control factors, and taking the athletes' athletic ability improvement as the system regulation goal, we constructed the system dynamics model of sports training function monitoring based on the mutual feedback relationship between athletes' function, training and recovery. Numerical simulation was also carried out to monitor the changes of aerobics athletes' function by taking their athletic training function as an example.

II. Construction of aerobics training load regulation monitoring model based on data mining

II. A. Construction of monitoring information collection model based on data mining

Association algorithm [24], [25] is an evolutionary algorithm of data mining techniques. Based on high-frequency exercise load monitoring information, Lian Li strong association rules are used to mine valuable information for predicting the amount of human exercise, which is used for subsequent analysis and decision-making.

Assuming that there exists $X \to Y$ strong association rules within database B and the set of frequent items is $(X \cup Y)$, the $X \to Y$ confidence can be estimated from the $(X \cup Y)$ support. The realization process is divided into the following two steps:

(1) Obtain the frequent itemset L_k from database B such that its support is greater than or equal to its minimum value $\sup_{\min}$.

(2) From the frequent item set L_k and its confidence minimum $conf_{\min}$, construct association rules such that $conf_{\min}$ is greater than or equal to the strong association rule confidence.

As an important factor of association rule mining, frequent itemsets need to be deeply explored. For the frequent itemset property, a layer-by-layer search cycle algorithm is used to find the itemsets, e.g., searching $(k+1)-$ itemsets by $k-$ itemsets. The searched frequent 1-itemsets are set as L_1, which is used as the basis for searching the frequent 2-itemsets L_2, and so on, until the itemsets cannot be searched.

Therefore, the initial stage of the mining process first calculates the frequency of occurrence of the itemsets containing a single element, and obtains the frequent 1-item set; at the k th step of the iteration, the MIFP-Apriori algorithm is utilized to obtain the frequent $k-$item set D_k from the frequent $k-1$ itemset L_{k-1}; and within the entire database B, the solution of which is the alternative support of each element of the option set D_k.

In summary, the association rule mining algorithm for collecting exercise load monitoring information is designed, and the specific process is described as follows:

(1) The frequent 1-item set L_i and the alternative 1-item set D_i are known, and the item set L_1 satisfies the following expression:

$$L_1 = \{d \in D_1 \mid \sup(d) \geq \sup_{\min}\} \tag{1}$$

where d refers to the alternative element whose support $\sup(d)$ is not less than the minimum support of the frequent 1-item set.

(2) Let $k = 2$ and the itemset L_{k-1} be a non-empty set; utilize the MIFP-Apriori algorithm to obtain the alternatives set D_k:

$$D_k = Apriori\_Gen(L_k - 1) \tag{2}$$

(3) If all transactions $B = | b_1, b_2, \cdots, b_n |$ are contained in the set of alternatives $D = \{D_1, D_2, \cdots, D_m\}$, then the set of alternative options D_k with the transaction b_i is a subset of D_{b_i}, where n denotes the number of transactions and the number of option sets, $i = 1, 2, \cdots, n$ respectively.

(4) For all the options in the subset D_{b_i}, count all the option sets and stop when the following expression is satisfied:

$$L_k = | d \in D_k \mid \sup(d) \geq \sup_{\min}\} \tag{3}$$

(5) If the set of frequent items L_k or the set of alternatives D_k is the empty set, the association rule R does not exist; conversely, the association rule between each exercise load monitoring information is established by the following equation:

$$R = D_k \cup (\alpha_k \to \beta_{k-1}) \tag{4}$$

where α_k and β_{k-1} are subsets of the full set of alternatives based on the subset D_{b_i}, whose confidence satisfies the following inequality conditions:

$$conf(\alpha_k \to \beta_{k-1}) \geq conf_{\min} \tag{5}$$

The sports load information acquisition model composed of microcontroller, data storage module and wireless communication module. The acceleration sensor and near-infrared spectrometer can be used to monitor the athletic load of the athlete, the monitoring data are stored in the storage module, and the valuable load information is sent to the intelligent terminal through the wireless transmission module to complete the acquisition operation after the association rule mining processing in the microcontroller. The intelligent terminal is mainly used to display the results of the collected load information and monitor the athletes' sports load status in real time.

II. B.Analysis of monitoring information collection results based on data mining

In order to verify the rationality of the design of the data mining system for biochemical indicators of sports training designed in this paper, the following experiments were conducted. First of all, the experimental parameters need to be set up, and the biochemical indicators of 100 athletes' sports (aerobics major) training in a sports academy were selected: hemoglobin (HB), blood creatine kinase (CK), blood urea nitrogen (BUN), and testosterone (T), and the data mining was carried out on the GoogleAppEngine platform, and the data sets were used as the input criteria, and divided into five groups according to different data volumes , respectively, on the traditional and the data mining system designed in this paper, as a way to verify the rationality of the design of the system.

Ⅱ. B. 1) Data mining rate results and analysis

The training biochemical index data of 100 athletes were grouped into five groups, and experiments were conducted in the traditional data mining system and the data mining system designed in this paper, and the time consumed by data mining was recorded, and the results of the comparison of the time consumed by data mining are shown in Table 1. When the amount of data collection is 2500, the traditional data mining system and this paper's data mining system consume the lowest time, respectively, 6.11s and 1.05s. When the amount of data collection is 10000, the difference between the two kinds of data collection consuming time increases significantly, and the time consumed by the traditional data mining system is 12.7 times more than that of this paper's method; when the amount of data collection reaches 15000, the time consumed by the traditional data mining system increases 12.7 times more than this paper's method; when the amount of data collection reaches 15000, the time consumed by the traditional data mining system increases 12.7 times. The time consumed by the traditional data mining system is 2010.42s, which consumes 21.9 times more time than the system in this paper (91.91s). It is clearly seen that the traditional data mining system consumes more time.

Table 1: Data mining takes time to compare results

Data collection	Traditional system detection time/s	Our system detection time/s
2500	6.11	1.05
5000	120.25	13.93
7500	322.82	29.88
10000	811.81	63.72
12500	1282.4	78.42
15000	2010.42	91.91

The results of the comparison of the mining rate of the two systems are shown in Fig. 1. From the figure, it can be more intuitively found that when the data were collected from 2500 to 15000, the time consumed by the data mining system in this paper only increased from 1.05s to 91.91s, while the traditional method increased from 6.11s to 2010.42s. In contrast, the rate of the data mining system for biochemical indicators of sports training proposed in this paper is significantly faster than the traditional data mining rate, and with the increase in the amount of data collection, the advantage of the data mining rate of the system is more obvious. The traditional data mining system has problems such as not being able to quickly analyze big data, which leads to a large amount of data backlog that can not be processed in time, which in turn reduces the rate of the system mining data.

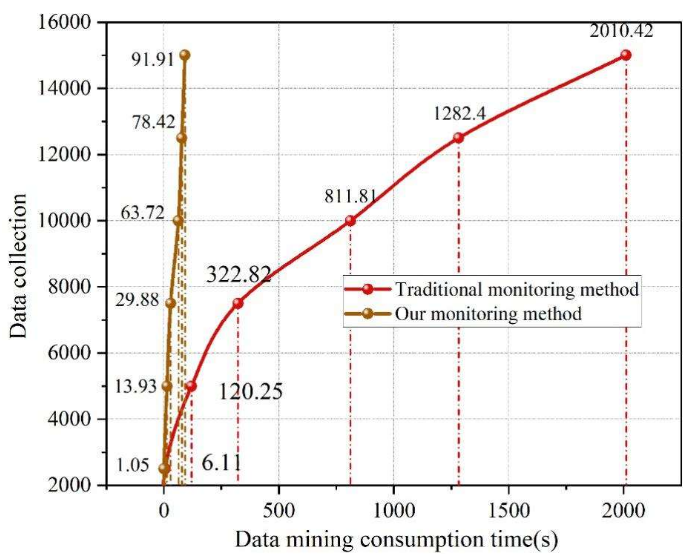


Figure 1: Two systems mining rate comparison results

Ⅱ. B. 2) Credibility results and analysis of data mining

Based on the association rule algorithm used in this paper for the data mining of biochemical indicators of sports training, the frequent 1 item with 20% support is selected, and the frequent 1 item is mined according to the steps, and the credibility of 70% is selected for mining, and the mining results are shown in Table 2. According to the 2nd rule illustrated that the credibility of the athletes with hematocrit (HB) index size range of 13~17 g/dL is 78.35%; the 4th rule illustrated that the credibility of the athletes with hematocrit (HB) index size range of 14~18 g/L is 83.89%; and the 6th rule illustrated that the athletes with blood creatine kinase (CK) index size range of 50~130 U/L credibility is 87.51%; for other athletes, the credibility of athletes with blood creatine kinase (CK) sizes ranging from 80 to 150 U/L is 100%. The design of the biochemical index data mining system for sports training designed in this paper has a high credibility for data mining and can provide a basis for the development of sports training models and training programs.

Table 2: Mining results

Rule number	Rule	Support / %	Credibility /%
1	Q1→W1	38.58	83.41
2	W1→Q1	38.16	78.35
3	Q2→W2	38.46	69.96
4	W2→Q2	38.13	83.89
5	Q1→E1	43.77	100
6	E1→Q1	43.67	87.51
7	Q2→E2	21.04	35.67
8	E2→Q2	22.92	100
9	Q2→E3	20.96	35.02
10	E3→Q2	22.07	97.73
11	R1→Q1	22.11	72.75
12	Q2→R2	44.35	80.43
13	R2→Q2	44.27	74.21
14	Q1→T2	37.57	84.48
15	T2→Q1	38.17	77.56

II. C.Aerobics training load regulation decision support system

Ⅱ. C. 1) System dynamics

System Dynamics (SD) is a branch of system science that combines system science theory with computer simulation to study the feedback results and behavior of systems. It is mainly used to study the relationship between the structure and dynamic behavior of complex systems. The theory suggests that the internal structures of a system interact with each other, and that its behavior or characteristics depend mainly on the causal and feedback relationships between the internal structures of the system.

Ⅱ. C. 2) System dynamics variables and variable equations

The main system dynamics variables are state variables, rate variables, auxiliary variables, and constants. The state variable represents the amount that can be accumulated and leaked inside the system, and its value is the sum of the original accumulation and the difference between the input flow and the output flow, which is able to describe the state of the system at any moment in time. If J is used to represent the past time point, K represents the present time point, L represents the future time point, JK represents the time interval from J to K, and KL represents the time interval from K to L, then its system dynamics equation (L equation) can be denoted as:

$$L \quad L.K = L.J + (RA.JK - RS.JK)DT \tag{6}$$

Where, L - represents the state variable, L.K - the new value of state variable calculated at moment K, L.J - the value of the state variable before the moment J, RA - denotes the flow rate that increases the state variable value, RA.JK - the value of the flow rate for increasing the stock in the time interval JK, RS - the streaming rate that represents a decrease in the value of the state variable, RS.JK - the value of the flow rate that decreases the value of the state variable in the JK time interval, DT - length of time between moment J and moment K.

The state-variable equation is a first-order difference equation, and when the solution interval is sufficiently small, the operation of the stock is practically equivalent to the integral operation, and its equation is equivalent to the following integral equation:

$$L = L_0 + \int_0^t (RA - RS)dt \tag{7}$$

Flow is the amount of change in flow per unit of time, and its input can be either a stock or a constant. The inputs and outputs of flow control the change in the system stock. The general form of the flow equation (R equation) is:

$$R \quad R.KL = f(L.K, C) \tag{8}$$

The meaning of the above equation can be understood as the magnitude of the flow rate in the KL interval value is determined by the value of the stock and the constant, and there is a functional relationship between them.

Auxiliary variables are intermediate variables describing the process, which are mainly used for information transfer and conversion between state variables and rate variables. The auxiliary variable equations (A equations) can be expressed as variables:

$$A \ \text{Variable name} = \begin{pmatrix} \text{Variable} \\ \text{Expression} \\ \text{Numerical} \end{pmatrix} \tag{9}$$

Constants are constant quantities in a system and their equations (C equations) take the form:
Variable name = value;
The initial value equation (N equation) and the constant equation (C equation);
The system dynamics model is a bounded system, so before the model can be run, the initial conditions of the system must first be determined, i.e., the initial value equations of the system must be determined. The generalized form is the same as the auxiliary variable equation.
The generalized form of the constant equation is: C variable name = value;
Table function equation (T equation);
When the relationship between the variables in the system can not be expressed by the functional relationship, it is often used to qualitative analysis and quantitative analysis of the combination of methods "empirical" description of the relationship between the variables, the form of the equation:

$$T \quad T = (\text{Variable quantity A value, variable quantity B value}) / (\cdots,\cdots) / (\cdots,\cdots) / \tag{10}$$

Ⅱ. C. 3) Dynamic Modeling of Athletic Training Function Monitoring System

The function monitoring system for the athletic training process [26] is shown in Figure 2. Functional monitoring of sports training is an important part of sports training, which is carried out throughout the whole process of sports training. From the beginning of the development of the training program, there are scientific researchers involved in the development of the functional monitoring program, the initial functional diagnosis, functional detection and evaluation, until the realization of the sports training goals. Therefore, in terms of sports training function monitoring personnel, its organizational form includes: coaches develop and implement training plans according to the training objectives; scientific research personnel develop corresponding function monitoring plans according to the training plans and arrangements of coaches, and monitor athletes' function indexes in combination with the actual situation of sports training and the arrangement of events, and conduct systematic and personalized evaluation and analysis of the monitoring results; The medical staff puts forward rationalized suggestions for the prevention of athletes' injuries according to the sports training arrangements and the injury characteristics of the sports, and actively diagnoses and treats athletes' injuries and diseases.

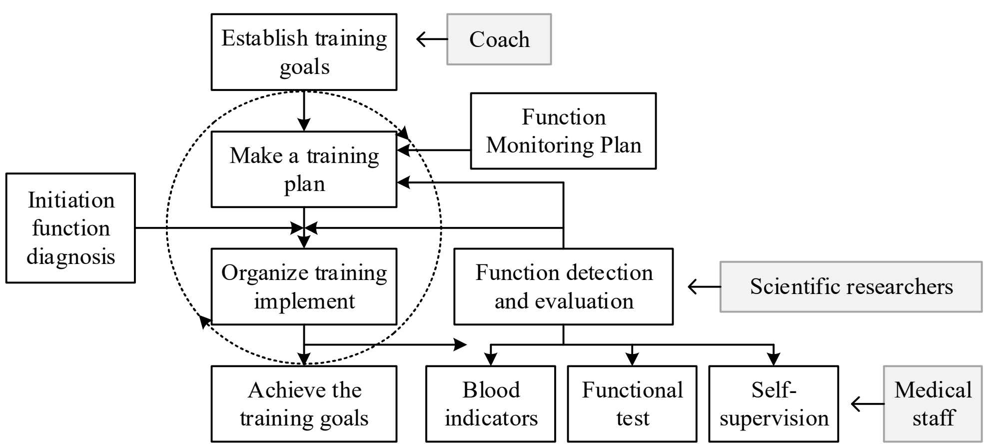


Figure 2: Functional monitoring system of exercise training process

It can be seen that sports training function monitoring is a complex system with multiple levels, multiple factors and multiple feedbacks. It involves training, competition, recovery, coaches, athletes, researchers, medical personnel, and the establishment of training goals, training program development, training program implementation and other elements. The elements of the system interact with each other, constrain each other, and form a certain feedback mechanism. Therefore, the factors affecting the monitoring of sports training functions include at least a dozen elements at the above 3 levels. In order to simplify the research problem, only 3 elements, namely, function, training and recovery, which are most directly related to function monitoring, were selected when defining the system boundary. Athletes' function is monitored through the system's dynamic changes in these 3 elements. The structure of the sports training function monitoring system is shown in Figure 3.

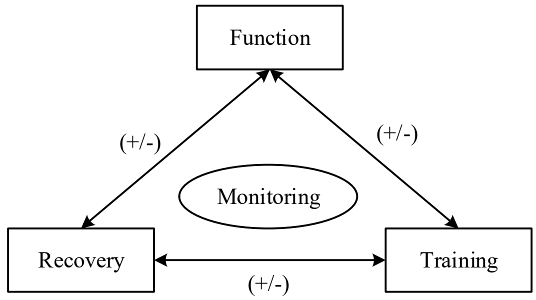


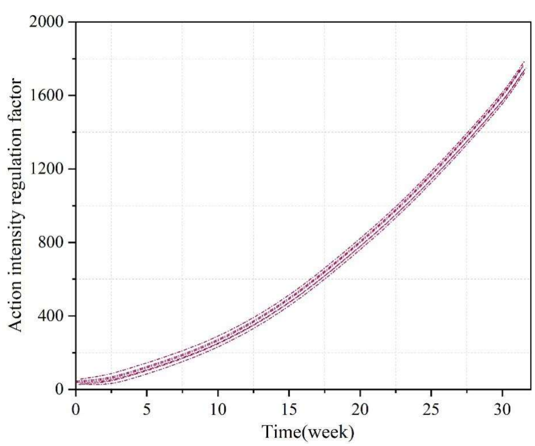
Figure 3: Structure diagram of the sports training function monitoring system

III. Analysis of the simulation effect of training load regulation on athletes' motor ability

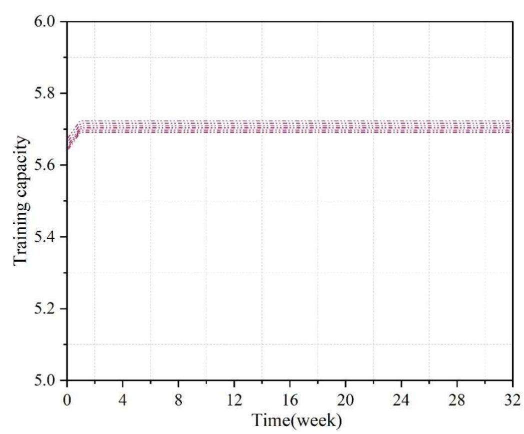
Ⅲ. A. Simulation results of training load regulation for athletes

The simulation time is 30 weeks in one academic year with a step size of 1. Simulation is performed under the initial state. The simulation results under the initial parameter values of athletes' aerobics training load regulation are shown in Fig. 4, where (a) ~ (d) represent the action intensity regulation factor, training capacity adaptation factor, action complexity regulation factor, and recovery cycle optimization factor, respectively.

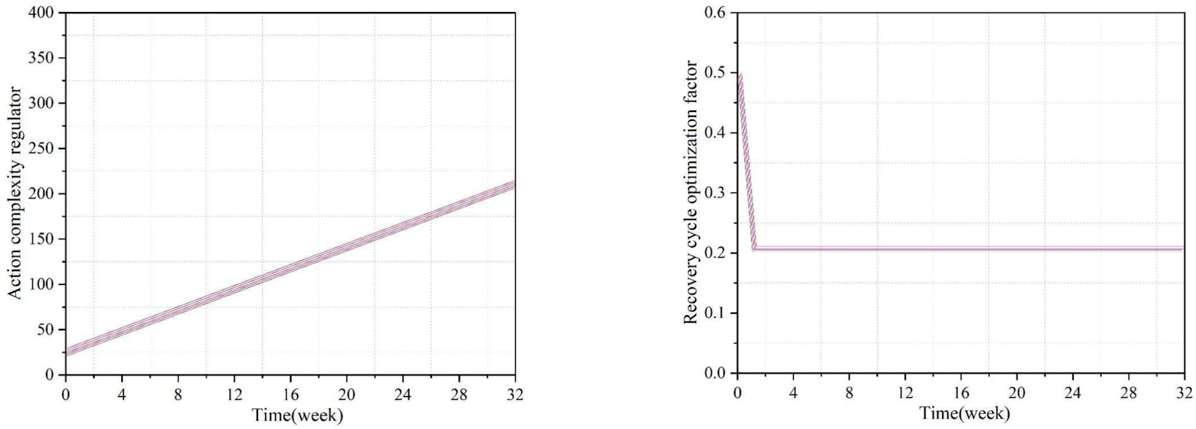
The movement intensity modulation factor increases with time. This incremental trend depends on the results of the interaction between the school, teacher, collective and athlete levels. In the initial phase, the increase in the training intensity of the athletes caused a dramatic increase in their training capacity fitness factor, which then showed a stable state. The recovery cycle optimization factor showed the opposite trend, in the initial stage, the recovery cycle optimization factor was relatively high, followed by a sharp downward trend, and finally in a stable state. As the recovery cycle optimization factor is affected by individual, training institutions and other factors. For example, the athlete's training content training autonomy is low, the training content arrangement is unreasonable, and the examination form is single. Usually, in the first few weeks of training, the athlete basically forms an attitude towards a certain training content training, and with the gradual increase in the level of training load and training movement intensity regulation factor of aerobics athletes, the recovery cycle optimization factor of the athlete will gradually decrease.



(a) Action intensity regulation factor



(b) Training capacity



(c) Action complexity regulator (d) Recovery cycle optimization factor

Figure 4: Simulation results of athletes' aerobics training load adjustment

Ⅲ. B. Analysis of numerical simulation results of aerobics training load regulation

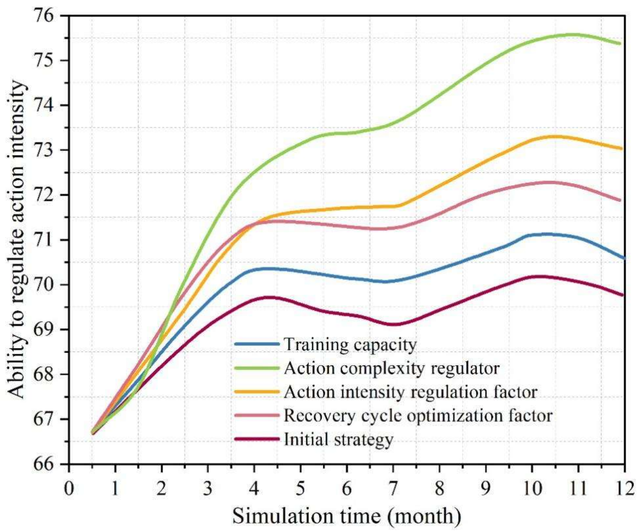
Based on the relationship between the regulatory factors and athletic ability in the system, different strategy programs were set up from the strategy dimensions of movement intensity regulation, movement complexity regulation and recovery cycle optimization to investigate the reasonable level of athletic ability that should be maintained under different enhancement strategies. Among them, the initial scheme is the current scheme of aerobics training, the movement intensity regulation, movement complexity regulation and recovery cycle optimization schemes respectively increase the parameter values of the corresponding dimensions of the regulatory factors by 20% on the basis of the initial scheme, while the enhanced movement complexity regulation scheme increases the parameter values of the regulatory factors of this dimension by 40%.

Ⅲ. B. 1) Results of Training Load Scheduling Analysis of Aerobics Athletes

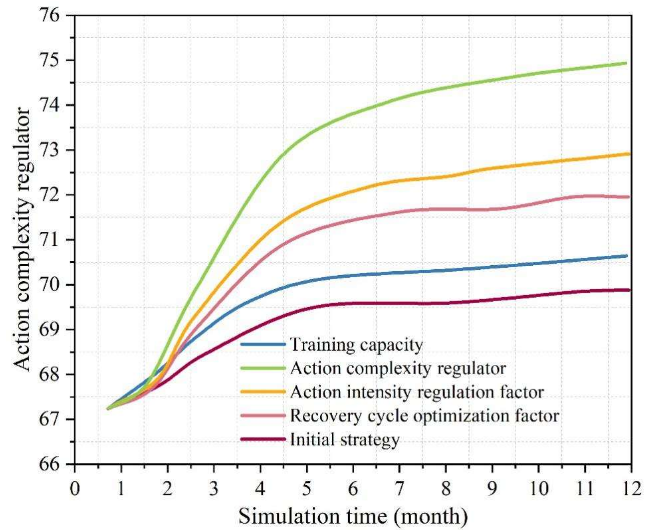
The results of the training load scheduling analysis of aerobics athletes are shown in Figure 5, where (a) to (d) represent the movement intensity regulation factor, movement complexity regulation factor, recovery cycle optimization factor, and training capacity adaptation factor, respectively. With the implementation of the intensity regulation factor, the athletes' familiarity with movement intensity regulation and training effect improved significantly, and the level of athletic ability increased rapidly. May-December, the athlete's training ability curve gradually leveled off, and reached 75.59 at 70.2 increase, indicating that the action intensity regulation has a greater effect on the enhancement of athletic ability but with conditional limitations. In addition, the enhancement effect of the recovery cycle optimization factor is more obvious, indicating that appropriate adjustment of the recovery cycle of the athlete's training load can enhance the athletic ability of aerobics athletes. The movement complexity adjustment factor rises more slowly at simulation time 0~2 months, indicating that at the initial stage of movement complexity adjustment, athletes have the situation of unawareness and psychological resistance. The change curve of the training capacity fitness factor shows that its enhancement effect is not significant under training capacity conditioning. Overall, under movement intensity regulation, movement complexity regulation, recovery cycle optimization and training capacity adaptation, the gymnasts' sport level ability was improved by 7.68%, 6.07%, 5.14% and 7.87%, respectively.

Ⅲ. B. 2) Effect of motor ability enhancement based on movement complexity regulation

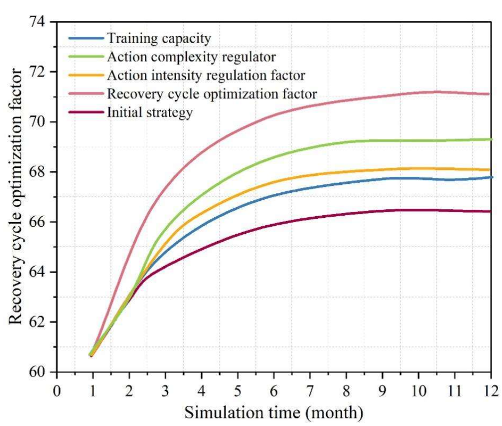
The effect of movement ability improvement of aerobics athletes is shown in Figure 6. Simulation time 0~February, the change curve of movement ability under the input strategy overlapped with the initial strategy, indicating that the athletes need a certain process of familiarization and adaptation to the new training equipment when implementing effective movement complexity adjustment. Simulation time 3~September, by increasing the adjustment of training intensity, training frequency and training duration, and timely updating the training data of the system testing process, the athletes' athletic ability constantly fluctuated upward. In the pre-implementation period of action complexity adjustment, the relative safety gain with the initial training program is negative, and with the adjustment of training content, the athletic ability is gradually improved, indicating that the adjustment of training content and athletic ability improvement has a time lag effect. It can be seen that the use of movement complexity adjustment as a single factor change quantity analysis found that the training load and athletic ability enhancement has a time lag effect.



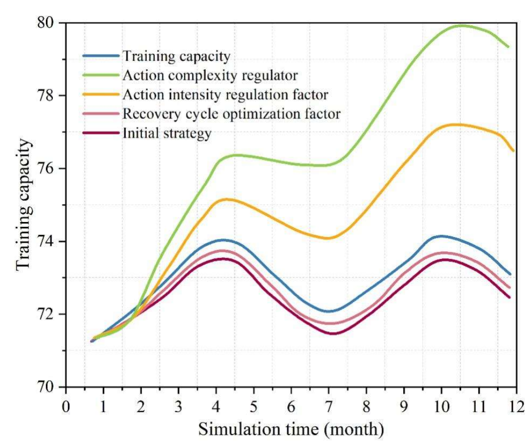
(a) Intensity control factor



(b) Action complexity regulator



(c) Recovery cycle optimization factor



(d) Training capacity suitability factor

Figure 5: Training load scheduling analysis results of aerobics athletes

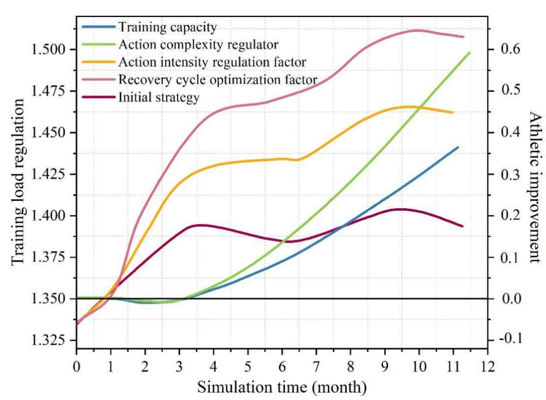


Figure 6: The ability of athletes to improve their movements

IV. Conclusion

In this paper, we first constructed a monitoring information collection model for training load regulation of aerobics athletes based on data mining, and then constructed a kinetic model of sports training function monitoring system based on the premise of system dynamics to provide decision support for training load regulation of aerobics athletes. The simulation results show that:

(1) The data mining rate of the system in this paper is fast, time-consuming and credible, which provides a more reasonable evaluation standard for the data mining of athletic biochemical indexes of aerobics athletes.

(2) Simulating the system of athletes' aerobics training load capacity, the level of athletic capacity was improved by 5.14%-7.87% throughout the cycle with a 20% increase in each of the regulation factors such as movement intensity regulation and movement complexity regulation. In addition, analysis using movement complexity regulation as a single factor change amount revealed a time lag effect between training load and athletic ability enhancement.

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