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Variation characteristic analysis of gymnast's physical agility based on biological rhythm model

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ABSTRACT

With the development of human society and the deepening and expansion of scientific research, chronobiology has been widely introduced into the field of sports science; the majority of scientists, coaches and athletes put more and more emphasis on research of the movement time, and pay attention to the relationship of sports and human biological rhythms. This article studies gymnast's athletic ability from the perspective of human biological rhythms. In the paper it first establishes the macroscopic and microscopic biorhythm mechanism model according to the rhythm characteristics of organisms, and analyzes the significance of the parameters in the mathematical model, then analyzes the circadian rhythm characteristics that presented by gymnast's heart and lung function indicator, blood and vital energy indicator, provides a more scientific reference for gymnastics strategy, finally analyzes the index reflecting the ability of gymnast's body function, and analyzes the biological rhythms characteristic of the hormone levels that can reflect the gymnast's muscle strength, speed, endurance and the ability of stress from the side. Through the analysis methods and results of the mathematical models and experimental data established in the text, it provides more scientific strategies for training and competition arrangements of gymnastics, meanwhile provides a theoretical basis for the study of biological rhythms characteristic.

Key words: Biological rhythms, physiological indicators, gymnast, peak time, exercise capacity

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INTRODUCTION

Organisms' various biological functional activity, growth, reproduction and some minor morphological structure are likely to exhibit a regularly repeated change with the passage of time, which is the biological rhythm; therefore the human biological rhythms and the movement training has some intrinsic link; reasonable use of human biological rhythms law has a very good effect on the improvement of sports training quality and athletic performance, through the grasp of the athletes' physiological, biochemical index changes, and similar circadian rhythm characteristic, use biological rhythm arrange and adjust the training plan, implement selected time training [1].

For the study of biological rhythms model and gymnasts' athletic ability many scholars have made their efforts; the research process and the integration degree of these two contents affect the development of gymnastics level; if we can use the biological rhythm to get a more scientific arrangements in gymnastics training process, then it can better promote the development of the sport; some domestic scholars give some opinions and conclusions, including: Wang Yi-wen [2] proposed the establishment of gymnast's biorhythm model, put forward scientific monitoring implementation, reasonable exercise stress arrangements, prevent sports injuries, improve training efficiency, overcome jet lag and so on during sports training process, in order to achieve the state of "the optimization" by adjusting the individual's competitive state; Ji Si-chao [3] revealed the effect of rhythmic theory on the results of competitive gymnastics, the results indicated that the physical, emotional and intellectual rhythms theoretical system did not apply to competitive gymnastics; Dong Ren-wei [4] explored the correlation between college student's cardiovascular endurance levels and stamina biological rhythms, obtained that the physical biological rhythms can

affect college student's cardiorespiratory endurance levels.

Based on previous studies, the paper takes the gymnast's exercise ability as the study object, establishes a macro-and micro-mechanism model of biological rhythms, at the same time collects the data condition of gymnast's heart and lung function indicator, blood and vital energy indicator, body function indicator and hormone level indicator, explores the effect of biological rhythm on the movement ability of the gymnast, and provides feasible advice for scientific training and competition arrangements of gymnastics. This article takes the biological rhythms characteristic of gymnast's athletic ability for example, studies the characteristics that human biological rhythms presents and the mathematical model of biological rhythms.

MATHEMATICAL MODEL OF BIOLOGICAL RHYTHMS

As a senior beings in nature, human body's system has many cycles and periodic rhythm phenomenon; these circadian rhythm phenomena will be regulated by its own internal feedback mechanism when subjected to external stimulus; the form roughly includes shifting frequency constant amplitude, shifting amplitude constant frequency, shifting frequency and shifting amplitude. This paper studies the biological rhythms, in order to reflect gymnast's athletic ability through the changing form of biological rhythms, so this chapter first analyzes the mathematical model of biological rhythms [5].

Biorhythm model can be established by the data and the mechanisms two angles; wherein the model based on the data is established by studying the statistical data of organism rhythm, ignore the complex mechanism of the living body, extract the external representation rule of the biological rhythm; and the model establishment based on the mechanism is on the basis of ignoring the secondary factor of rhythms mechanism, then conduct reasonable assumptions for the model, extracts main mechanism factors from the system, and finally uses the main mechanism factors to build the model, the following is the main analysis on the mechanism model of biological rhythms.

The mechanism model of macroscopic type biorhythm: From a biological perspective, during the movement process the body will improve the oxygen consumption rate; the human body will internally adjust the amplitude and frequency of the heart beat rhythm through a variety of enzymes and nervous system and other feedback mechanism, so as to improve the rate of pumping blood; this section establishes the macro-type mechanism model taking heart rhythm as an example; the heart beat is an inherent human rhythm phenomenon, its role is to pump blood through the heart contraction of each rhythm cycle, to meet the oxygen needs of human body.

In order to establish a reasonable macroscopic mechanism model of heart rhythm, the model should meet the four characteristics:

- When the change of oxygen consumption rate is smaller, the amount of blood that the heart beat delivers can meet the oxygen needs of the body in time;
- When the change of oxygen consumption rate is large, the rhythm adjustment of heart beat cannot keep up with the needs of dependents, after the radical movement there will be a temporary hypoxia phenomenon;
- When the oxygen consumption rate returns to normal levels after a sharp rise, heart rhythm has a lag effect, that is after the radical exercise, the rate of heart beats will still be fast; only after a period of time the heart beat rate will return to normal levels; and there is compensation within this period of time for the hypoxia amount of upper stage;
- When the amplitude changing rate of the heart beat is smaller than the frequency variation, the distribution of the amplitude changing amount can be set by using the parameters.

For the reliability and handle ability of the model building, the model has the following three tips:

- In order to meet the needs of body oxygen consumption, heart needs feedback adjustment on its beat amplitude, and its criteria is the instantaneous value of the oxygen consumption;
- Heart beat rhythm is only affected by the rate of oxygen consumption;
- The heart has no lag for the perception of oxygen consumption rate.

In the above hypothesis, we have the basic description equations of the beating heart, as defined in formula (1) below.

$$y = A(t)\sin[2\pi t \cdot f(t)] \tag{1}$$

In Formula (1) $f(t)$ represents the actual frequency of the heart rhythm, $A(t)$ indicates the actual amplitude of

the heart rhythm, y represents the displacement of the heart beat.
If the oxygen consumption rate is positively proportional to the rate of blood volume delivery, and the blood volume delivery is positively proportional to the product of double frequency and amplitude, meanwhile introduce the time constant k, and then it satisfies the relationship in formula (2) below.

$$2kf_g(t)A_g(t)=I(t) \tag{2}$$

In formula (2) $f_g(t)$ represents the target frequency of heart rhythm, $A_g(t)$ represents the target amplitude of heart rhythm, and $I(t)$ means the oxygen consumption rate. Human heart rhythm frequency and amplitude cannot increase unrestrictedly in movement, and we know the lower limit of oxygen consumption rate is zero; in order to reflect the limit of physiological factors, the text set up $V_{\max}$ to represent the maximum rate of oxygen consumption.

The human body's oxygen consumption will increase during exercise, and the heart rate will significantly increase two; heart rate amplitude is fairly stable compared to heart frequency, but there will still be a slight variation; in order to denote the variation quantity we introduce an allocation factor β; If the factor is 0, then heart rate amplitude will remain constant, and the frequency change will be responsible for all the increase amount of oxygen, therefore we can obtain the formula (3).

$$\frac{dA_g(t)}{A_g(t)}=\frac{df_g(t)}{f_g(t)} \tag{3}$$

The frequency and amplitude change may be as described in the formula (4) and (5).

$$y=\frac{2V_{\max}}{\pi}\arctan\left(\frac{\pi}{2V_{\max}}x\right) \tag{4}$$

$$\frac{dA(t)}{dt}=\frac{2V_{\max}}{\pi}\arctan\left(\frac{\pi}{2V_{\max}}\left(A_g(t)-A(t)\right)\right) \tag{5}$$

In the formula (4) when the relation satisfies $y'=0$, then $\Delta x=\Delta y$; when $x\to\infty$, then $y=\pm V_{\max}$; y is the odd function. The macro-type mechanism model to describe the beating heart rhythms can be seen as the equations as in formula (6) below.

$$\begin{cases} y=A(t)\sin[2\pi t\cdot f(t)] \\ \dfrac{df(t)}{dt}=\dfrac{2V_{\max}}{\pi}\arctan\left\{\dfrac{\pi}{2V_{\max}}\left[\left(\dfrac{I(t)}{2kc}\right)^{\frac{1}{\beta+1}}-f(t)\right]\right\} \\ \dfrac{dA(t)}{dt}=\dfrac{2V_{\max}}{\pi}\arctan\left\{\dfrac{\pi}{2V_{\max}}\left[\left(\dfrac{I(t)}{2kc}\right)^{\frac{\beta}{\beta+1}}-A(t)\right]\right\} \end{cases} \tag{6}$$

The mechanism model of microscopic type biorhythm: Physiology, metabolism and behavior processes of all living body in general shows circadian rhythm of 24-hour cycle; in order to study the biological rhythm of gymnasts and explore their athletic ability, this section establishes mechanistic model of micro-type rhythm taking the change rhythms of body temperature establishment as background; in order to extract the affecting situation of the main factors, the paper establishes spring oscillator model that reflects the circadian rhythm.

Body temperature rhythm characteristics have the following five characteristics:

- The observation of temperature has a stable equilibrium;
- When the external input does not exist, the temperature observation will maintain at their shock;
- When the external input is constant, the temperature observation will remain the same period, but the amplitude will decay over time;
- When the temperature observation receives the input, the change condition will tend to synchronization;
- When the external input has phase transition, the temperature observation occur disorder, but it will gradually become synchronized with the external input.

In order to extract the major laws of body temperature rhythm, especially the model follows two assumptions below:

- The inherent mechanism inside of the organism of the object will not change in a short time;
- The period circadian rhythm the temperature observation is reflected by amplitude, frequency and phase.

The physical model of spring oscillator is shown in Fig.1.

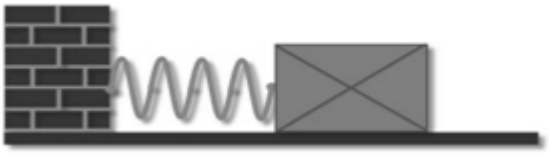

Fig.1: The physical model schematic of spring oscillator

As shown in Fig.1, the observation amount of the temperature is regarded as the spring, the external input is seen as external force, the internal system's obstacles to the observation amount can be seen as resistance, and we can obtain the dynamic equations of spring oscillator system, as shown in equation (7).

$$m\ddot{x}(t)+kx(t)+b\dot{x}(t)=f(t) \tag{7}$$

In the formula (7) $x(t)$ represents the difference between the observation and stable point of organism's circadian rhythm phenomena; m represents inertia of observations; k indicates the recovery ability to a stable state; b means the hinder ability to the change of observation amount; $f(t)$ means external associated input. The left side of formula (7) is only related with the organism, and in the control system theory it can be seen as system internal mechanism; and the left side of the equation represents some external input means; for each given input, we can get an unique output by solving the second-order differential equation shown in equation (7); the structure of the input, the system and the output is shown in Fig.2.

Fig.2: The input-output schematic of the system

Typically, the organism is in a certain state m,k,b can be considered as a constant; only when the state of the organism changes significantly, m,k,b will also change accordingly and then change to another constant. Typically the status change of organism will not be too obvious. When the external input will not change again, that is $f(t)=c$ and c is a constant, equation (7) turns into a second-order differential equations with constant coefficients, and its characteristic equation is in the formula (8) below.

$$a^2+\frac{b}{m}a+\frac{k}{m}=0 \tag{8}$$

To make the formula (7) have a periodic solution, the parameters must satisfy equation (9).

$$\frac{b^2}{m^2} < \frac{4k}{m} \tag{9}$$

The solution of two-order differential equations with constant coefficients in Formula (7) is shown in equation (10) below.

$$x(t) = c_1 e^{-\frac{b}{m}t} \cos \omega t + c_2 e^{-\frac{b}{m}t} \sin \omega t + \frac{c}{k} \tag{10}$$

In the formula (10) ω represents the angular frequency, and the value is in the formula (11); the value of the constant c_1, c_2 is determined by the initial state; when the external input has a periodic variation, we can suppose the input function as shown in formula (12); generally $\omega \approx \omega_0$, then the solution of the differential equation is shown in the formula (13) below.

$$\omega = \frac{1}{2}\sqrt{\frac{b^2}{m^2} - \frac{4k}{m}} \tag{11}$$

$$f(t) = c + A\cos(\omega_0 \cdot t) \tag{12}$$

$$x(t) = c_1 e^{-\frac{b}{m}t} \cos \omega t + c_2 e^{-\frac{b}{m}t} \sin \omega t + \frac{c}{k} + \frac{A}{\sqrt{\left(b - m\omega_0^2\right)^2 + k^2\omega_0^2}} \cos\left(\omega_0 t - \varphi\right) \tag{13}$$

GYMNAST'S EXERCISE CAPACITY BASED ON THE BIORHYTHMS ANALYSIS

Gymnast's biorhythms analysis: This paper analyzes the circadian rhythms characteristic of gymnast's cardiovascular function, respiratory function, blood and vital breath indicator; wherein cardiovascular function and respiratory function are collectively known as cardiopulmonary function indicator, which is an important factor affecting the endurance quality of athletes, also is the most commonly used indicators of the movement medical supervision. The experiment shows gymnast's cardiopulmonary function is the same as athletes of other projects, but also has significant time rhythm. Table 1 and Table 2 shows the circadian rhythm characteristics of cardiovascular and respiratory function in the gymnastics practice.

Table 1: The circadian rhythm characteristics of the gymnast's cardiovascular function

Cardiovascular indicators	Median level	Peak time	P values
1	0.790	18:23	<0.05
2	18.33	18:42	<0.05
3	11.03	18:20	<0.05
4	37.11	16:18	<0.05
5	6.080	17:05	<0.05
6	5.720	17:10	<0.05
7	14.72	18:24	<0.05

Note :1-7 represents cardiac blood ejection velocity (m / s), blood ejection acceleration (m/s2), blood ejection distance (cm), cardiac index (l/min/m2), cardiac output (l / min), cardiac work (kg / m) and systolic pressure (KPa)

From the data in Table 1 we can obtain the distribution feature of each cardiovascular indicator value at peak time drawn as shown in Fig.3.

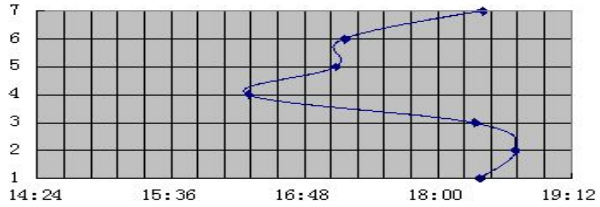

Fig.3: The distribution feature of the cardiovascular indicators at the peak time

The Fig.3 shows that the peak moment of cardiovascular indicators 1,2,3,7 is concentrated between 8:00-19:00; the peak moments of overall seven indicators are between 16:00-19:00; that is if the gymnasts compete between 16:00-19:00, the cardiovascular indicators will show its best state.

Table 2: The circadian rhythm characteristics of the gymnast's respiratory function

Cardiovascular indicators	Peak time	Variation ranges
1	18:00	16:00-22:00
2	06:00	05:00-07:00
3	18:00	17:00-21:00
4	18:00	16:00-20:00

Note :1-4 represents vital capacity, lung resistance, oxygen uptake and respiratory rate

Data in Table 2 shows the distribution feature of four indicators of gymnast's respiratory function values at the peak moments; as can be seen, in addition to pulmonary resistance peak is concentrated in 06:00, remaining three indicators focus on18:00; the data in Table 1 and Table 2 shows when athlete exercise between 16:00-19:00 his cardiopulmonary function is optimum, which is the biological causes that in the afternoon the body fitness and sports performance is higher than that in the morning; thus generally experienced coaches will arrange physical training in the afternoon and evening, and some important games are held in the evening.

Gymnast's blood and vital breath indicator primarily reflects the function of the body transportation and maintain acid-base balance; these above two functions are important factors affecting gymnast's physical fitness, similarly the gymnast's blood and vital breath indicator also has its own rhythm characteristics in the circadian time; the data in Table 3 shows the circadian characteristics of gymnast in a quiet state.

Table 3: The circadian rhythm characteristics of the gymnast's vital energy and blood indicators

Vital energy and blood indicators	Median value	Peak time	P values
1	130.8	15:30	0.005
2	44.55	05:17	0.236
3	4.300	03:06	0.054
4	7.020	11:54	0.732
5	24.40	16:10	<0.001
6	21.30	16:06	<0.001
7	7.290	17:12	<0.001

Note :1-7 indicates hemoglobin (g / H), oxygen saturation (%), the oxygen partial pressure (KPa), carbon dioxide partial pressure (KPa), bicarbonate radical ion (KPa), standard bicarbonate (KPa), and PH value

According to the data in Table 3 we can obtain the distribution feature of gymnast's blood and vital energy indicator at the peak moment in a quiet state as shown in Fig.4.

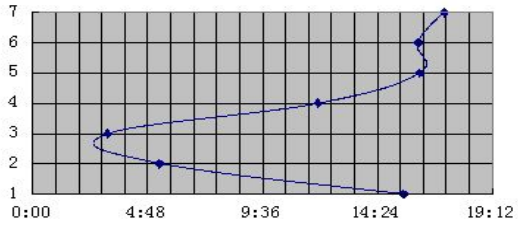

Fig.4: The distribution feature of vital energy and blood indicators at the peak time

As can be seen in Fig.4 a lot of blood and vital energy indicators of the gymnasts and other athletes can show a significant circadian variation in the quiet state, and therefore a reasonable training program should also take athlete's blood and vital energy indicators into account.

The rhythm analysis of gymnast's physical fitness changes: Since the human physical ability is the integrative biology function ability demonstrated by the body during exercise, gymnast's fitness, hormone levels and changes in body temperature also show a similar circadian rhythm characteristic. If the body's function is divided in accordance with the physical part, it can be divided into the overall function capacity and local function capabilities; in the premise of understanding the physical rhythmic characteristics of gymnasts, it has very important meaning for the selection of outstanding athletes and accurately understanding of the athletes' physiological function state.

Table 4 shows the circadian rhythm characteristics of gymnast body's total work ability and local work ability.

Table 4: The circadian rhythm characteristics of the gymnast's human performance

Human performance indicators	Peak time	Variation range
1	19:28	18:00-20:00
2	17:00	16:00-18:00
3	17:00	16:00-18:00
4	17:30	17:00-18:00
5	17:00	16:00-18:00
6	15:00	12:00-17:00

Note :1-6, denotes: overall physical fitness, runaway speed, 100 meters sprint speed, the speed of hand slap, pinch strength and push-ups

Table 4 shows the gymnast's circadian rhythm characteristics; the blood concentration levels of testosterone and cortisone and biological rhythms characteristic directly affect the muscle strength, speed, endurance, stress ability and other abilities that are closely related to sports performance. The blood concentration features of above two hormones also show circadian rhythm characteristics; the rhythm characteristics of these two hormones can reflect gymnast's muscle strength, speed, endurance and stress ability from the side, as shown in Table 5.

Table 5: The circadian rhythm characteristic list of the gymnast's blood testosterone and cortisone content

Hormone indicators	Median level	Peak time	P values
Testosterone(mol/L)	23.140	07:00	<0.05
Cortisone(mol/L)	218.08	06:00	<0.05

For the establishment of gymnast's biorhythm model, it refers to conduct the model processing for the cyclical changes of each athlete's physiological and biochemical indicators; and then come to each study content's rhythm curve, the corresponding parameters, the best moment of functional status, median level and the normal variation range; and finally come to a reasonable training program and scientific match schedule through the model results.

CONCLUSION

Based on the biorhythm model building method of macroscopic mechanism, this paper analyzes the biological rhythms significance of each parameter in the mathematical models; it analyzes the spring oscillator model, analogies the body temperature rhythm characteristics of the gymnast, turns the body temperature rhythm into a solving process of second-order differential equation, and provides a good analysis method for the biological rhythm analysis; it obtains by the circadian rhythm characteristics of gymnast's heart and lung function through experimental data, gives the arrangements strategy of appropriate training and competition time for gymnasts, analyzes the reasonableness of arrangements time for today's most important sporting matches; meanwhile this paper presents the circadian rhythm characteristics of the vital energy and blood indicator for gymnast in the quiet state, and on the other hand provides a reference for athletes to make scientific training and competition arrangements; in order to explore the capability characteristics of gymnast's human performance, the paper gives the circadian rhythm characteristics of the human function, analyzes the impact of rhythm on gymnasts' exercise ability, analyzes rhythm changes of athlete's muscle strength, speed, endurance and stress capacity from the side by the rhythm change conditions of hormone levels in the blood; finally, this paper gives the parameter data and model building purposes that human biological rhythms model need, provides more scientific strategy for gymnasts' training and match schedule through the model and the solution of the model.

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