CARDIOVASCULAR CONTROL RESPONSES IN HIGH INTENSITY EXERCISE STRESS TESTS

RESPOSTAS DE CONTROLE CARDIOVASCULAR EM TESTES DE ESTRESSE DE EXERCÍCIOS DE ALTA INTENSIDADE

RESPUESTAS DE CONTROL CARDIOVASCULAR EN PRUEBAS DE ESTRÉS DE EJERCICIOS DE ALTA INTENSIDAD

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ABSTRACT

Introduction: High intensity exercise is an important factor to achieve the best exercise effect, and is closely related to the patient's safety and rehabilitation. Objective: To investigate the effects of high intensity exercise on cardiovascular response and substance and energy metabolism. Methods: 50 male students at a university were selected. The average age of the subjects was 23 years old. Process of the experiment: Before the experiment, each subject took routine warm-up activities first, then put on the experimental equipment and began to run 100 meters. At the same time, the subjects' heart rate, blood oxygen parameters and exercise time were recorded. After passing the finish line, a period of heart rate recording and blood oxygen parameters were continued. Results: Anaerobic metabolism was the main activity in the 100m race. The first 7s after the start of the race, there is a non-lactic acid process without oxygen metabolism, and the muscle oxygen saturation curve presents little change. Conclusions: High intensity exercise in sports training and physical exercise can lead to reduced heart rate variability. The increased incidence of various arrhythmias should be based on the actual situation of the movement of the object, and a reasonable arrangement of exercise load intensity. ***Level of evidence II; Therapeutic studies - investigation of treatment results.***

Keywords: Physiology; High-Intensity Interval Training; Exercise.

RESUMO

Introdução: Exercícios de alta intensidade são um importante fator para alcançar o melhor efeito de exercícios, e está estreitamente ligado a segurança e reabilitação do paciente. Objetivo: Investigar os efeitos de exercícios de alta intensidade na resposta cardiovascular e no metabolismo de substâncias e energia. Métodos: 50 estudantes do sexo masculino em uma universidade foram selecionados. A idade média dos sujeitos do estudo era de 23 anos. Processo do experimento: Antes de iniciar, primeiramente, cada estudante fez aquecimentos de rotina. Após, colocaram o equipamento experimental e começaram a correr 100 metros. Ao mesmo tempo, a frequência cardíaca, parâmetros de oxigenação do sangue e tempo do exercício foram registrados. Após passar a linha de chegada, continuou-se a registrar a frequência cardíaca e os parâmetros de oxigenação do sangue por um tempo. Resultados: O metabolismo anaeróbico foi a atividade principal na corrida de 100 metros. Nos sete segundos após o início da corrida, há um processo ácido não láctico sem a metabolização de oxigênio e a curva de saturação de oxigênio do músculo apresenta pouca alteração. Conclusões: Exercícios de alta intensidade no treinamento esportivo e o exercício físico pode levar à variabilidade reduzida de frequência cardíaca. O aumento na incidência de várias arritmias deve se basear na situação real de movimento do sujeito e um manejo razoável da intensidade da carga do exercício. ***Nível de evidência II; Estudos terapêuticos – investigação de resultados de tratamento.***

Descriptores: *Fisiologia; Treinamento Intervalado de Alta Intensidade; Exercicio Físico.*

RESUMEN

Introducción: Ejercicios de alta intensidad son un importante factor en alcanzar el mejor efecto de ejercicio, y está estrechamente relacionado a la seguridad y rehabilitación del paciente. Objetivo: Investigar los efectos de ejercicios de alta intensidad en la respuesta cardiovascular y en el metabolismo de sustancias y energía. Métodos: Se seleccionó 50 estudiantes del sexo masculino en una universidad. La edad media de los sujetos del estudio era de 23 años. Proceso del experimento: Antes de empezar, primeramente, cada estudiante hizo calentamientos de rutina. Después, pusieron el aparato experimental y empezaron a correr 100 metros. Al mismo tiempo, se registró la frecuencia cardíaca, parámetros de oxigenación de la sangre y el tiempo del ejercicio. Después de pasar la línea de llegada, se continuó a registrar la frecuencia cardíaca y los parámetros de oxigenación de la sangre por un tiempo. Resultados: El metabolismo anaeróbico fue la actividad principal en la carrera de 100 metros. 7 segundos tras el comienzo de la carrera, hay un proceso ácido no láctico sin la metabolización de oxígeno y la curva de saturación de oxígeno del músculo presenta poca alteración. Conclusiones: Ejercicios de alta intensidad en el entrenamiento deportivo y el ejercicio físico puede llevar a la variabilidad reducida de frecuencia cardíaca. El aumento en la incidencia de varias arritmias debe basarse en la situación real de movimiento del sujeto y un manejo razonable de la intensidad de carga del ejercicio. ***Nivel de evidencia II; Estudios terapéuticos – investigación de resultados de tratamiento.***

Descriptores: *Fisiología; Entrenamiento de Intervalos de Alta Intensidad; Ejercicio Físico.*

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INTRODUCTION

With the change of people's lifestyle and improvement of living standard, cardiovascular disease has become a major public health problem that endangers and threatens human health.[1] At present, the prevalence and mortality of chronic cardiovascular diseases are still on the rise in China, with about 290 million people suffering from these diseases, which makes the burden of cardiovascular diseases in China increasingly aggravating, requiring medical personnel to pay high attention to and control them.

Exercise therapy is the core content of cardiovascular function training, which can improve the cardiac function reserve of patients with heart disease. For patients with cardiovascular diseases, the traditional exercise prescription is continuous moderate intensity continuous exercise, including walking, running, Taijiquan, etc., but the optimal exercise intensity that can achieve the maximum exercise effect is still controversial.[2,3] JFBA B. et al. easily influenced resistance and aerobic exercise with different effects by engaging in physical exercise training. With the increasing popularity of eliminating high-intensity cross-training (HICT), there is little information about the effect of this mixed modal exercise stimulation on arterial stiffness.[4]

METHOD

Subjects

Before the high-intensity (100-meter run) experiment, in order to study the possible movement rules, we carried out the pre-experiment of high-intensity exercise, including in-situ fast running and electric running platform experiment, with a total of 120 people. In the experiment, it was found that the heart rate of some subjects did not fall into the recovery stage with the end of external load at the moment of the end of exercise, but there was a process of the heart rate continued to rise rapidly. The amount of oxygenated hemoglobin in the exercise muscle group decreased during exercise, and the concentration of oxygenated hemoglobin continued to decrease at the moment the subjects finished exercise, before entering the recovery stage.[5] Considering that the stimulation intensity of fast running in situ and running platform experiment is not enough, in order to deeply study the movement rule of high-intensity exercise, the 100-meter running experiment was carried out on the standard track in the stadium. Selection of subjects: the subjects were mainly composed of 50 male college students in a certain university. The average age of the subjects was 23 years old and they were in good health. All the above subjects had good physical fitness and had good daily exercise habits. Process of the experiment: Before the experiment, each subject took routine warm-up activities first, then put on the experimental equipment and began to run 100 meters. At the same time, the subjects' heart rate, blood oxygen parameters and exercise time were recorded. After passing the finish line, a heart rate record and blood oxygen parameters were continued to be collected, and the experiment ended.[6]

Determine the data collection site

Real-time heart rate collection is based on the existing Suunto heart rate band, which is routinely worn[7]. Tissue oxygen collection site is a large amount of work in the process of running quadriceps femoris, take the upper 10 cm of the middle of the patella, fixed with elastic band. The heart rate data relay repeater and tissue oxygen data register are fixed at the upper arms on both sides with elastic bands respectively.

RESULTS

Characteristics of heart rate changes after high-intensity exercise

In the high-intensity 100-meter race, the participants' heart rates continued to rise as they crossed the finish line, then slowly returned to a quieter level. This phenomenon can be described graphically, as shown in Figure 1, the data image of a subject. Firstly, the characteristic images of heart rate changes of high-intensity subjects are given.

TS: Movement time of the subject, unit: second

TR: Time (in seconds) from the end of the subject's exercise to the end of the experiment

T1: the time (in seconds) at the end of exercise until the subject's heart rate rises to the highest value

HR(T): The function of heart rate against time, which can be regarded as a continuous function or a discrete function according to different situations, unit :1/ min

HRmax: Maximum heart rate, unit :1/ min

In the figure above, the starting time is the time when the subjects start to run. After time TS, the exercise ends (marked by the green line), and after time T1, the exercise heart rate reaches the maximum value (marked by the blue line), and then slowly returns to the pre-exercise level (marked by the green line to the end of the experiment, the time is TR). As you can see, the heart rate continues to rise immediately after the high-intensity exercise (the 100-meter run) stops, until it reaches its maximum, and then slowly returns to its quieter level. In the high--intensity exercise experiment, the most concerned phenomena are the amplitude of increase of heart rate per unit time (curve slope), the maximum heart rate (function maximum value) and time T1 at the end of exercise. Considering the asymmetry of the heart rate curve in the ascending and descending stages, the method of piecewise data fitting was adopted. Meanwhile, the ascending stage was mainly used in the analysis of the curve image. For the degree of the polynomial function, according to the fitting result and considering the universality of the method, the degree of 4th polynomial is adopted (but the actual degree may be lower than 4) :

$$HR(t) = \sum_{i=0}^{4} c_i t^i \qquad (1)$$

The fitting form of exponential function is as follows:

$$HR(t) = \sum_{i=0}^{1} c_i e^{k_i t} \qquad (2)$$

The above four parameters, the heart rate at the end of exercise, the increase of the heart rate per unit time at the end of exercise (the end of

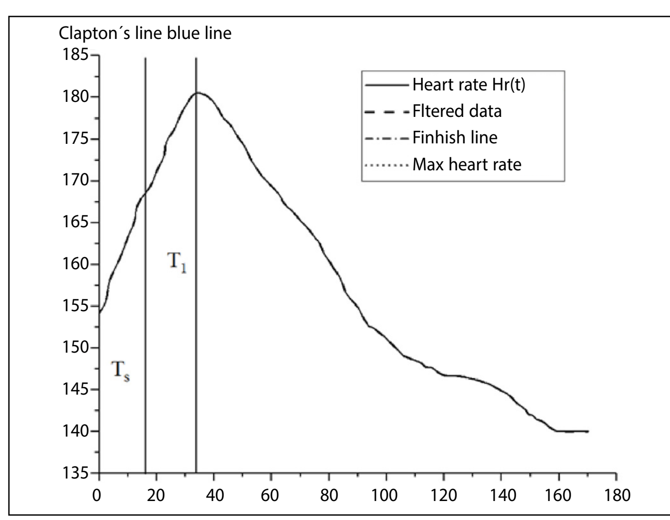

Figure 1. Heart rate characteristic chart of subjects with high intensity exercise.

exercise, slope of heart rate curve) can be obtained by fitting function, and the maximum heart rate and parameter T1 can be directly calculated from data (parameter T_1 can first calculate the time corresponding to the maximum heart rate, and then subtracting the exercise time). After calculation, it is shown in Table 1:

The exponential function fitting is also used to select the form $HR(t)=\sum_{i=0}^{1} c_i e^{k_i t}$ of the basis function (Again, depending on the situation, there can be a different number of exponential functions). Relevant parameters of subjects can be obtained as shown in Tables 2 and 3.

Changes of tissue oxygen after high-intensity running

The changes of oxygenated hemoglobin in the blood oxygen parameters continued to decline at the end of the exercise, reached the lowest level, and then slowly recovered. The characteristic images are shown in Figure 2. Points in Figure 2 are the number of data points. The curve is the connection of adjacent data. The straight line represents the time when the subject arrives at the end point. As you can see from this graph, the amount of oxygenated hemoglobin changes continues to decrease after the subjects reach the end point until they reach a minimum and then slowly return to normal levels.[8,9]

We then conducted sports tests on dozens of people in a certain university,Almost all athletes with good training level showed similar phenomenon. Example Figure 3.

DISCUSSION

In Figure 3, the left side of line A is the state of the athlete before the start of the race, and the whole process of the athlete's 100-meter race

Table 1. polynomial data fitting calculation parameters.

Serial number	End of exercise heart rate (1/min)	Heart rate increase (1/min/second)	Maximum heart rate (1/min)	Parameter T1(second)
1	155.17	0.5094	186.00	7.58
2	169.04	1.7581	180.48	13.57
3	180.39	0.4959	202.00	10.78
4	167.43	0.8839	181.20	8.59
5	153.11	1.5691	175.00	6.16
6	162.66	1.4196	183.00	7.30

Table 2. Exponential function fitting calculation parameters.

Serial number	End of exercise heart rate (1/min)	Heart rate increase (1/min/second)	Maximum heart rate (1 / min)	Parameter T1(second)
1	154.76	0.9341	186.00	7.58
2	160.61	1.8662	180.48	13.57
3	178.50	0.9641	202.00	10.78
4	166.66	0.8616	181.20	8.59
5	152.19	1.4212	175.00	6.16
6	162.67	1.3989	183.00	7.30

Table 3. Characteristic parameters of 100-meter run calculated by polynomial fitting method.

Serial number	Intensity of exercise during exercise (1/min)	Average heart rate change during exercise (1/min/second)	Rise of heart rate at the end of exercise (1/min/second)	Maximum heart rate (1/min)
1	147.0431	1.9280	0.5094	186.00
2	148.5879	2.4006	1.7851	180.48
3	172.1830	1.0755	0.4959	202.00
4	160.1510	0.9754	0.8839	181.20
5	141.8614	1.4292	1.5691	175.00
6	150.6309	1.7458	1.4196	183.00

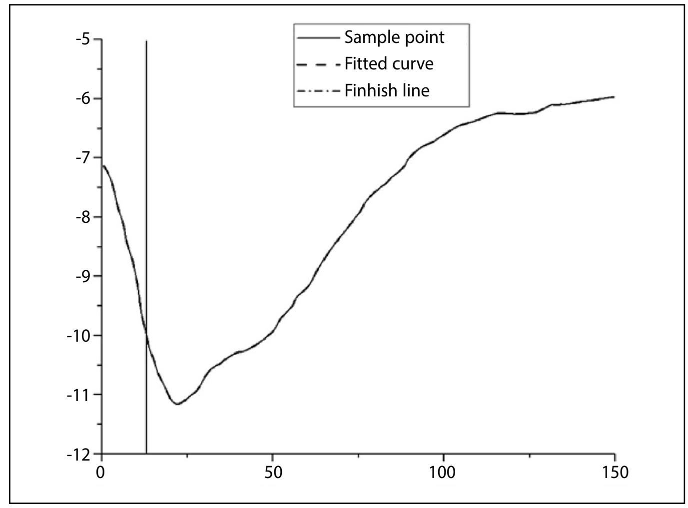

Figure 2. The variation of oxygenated hemoglobin in subjects with high intensity exercise.

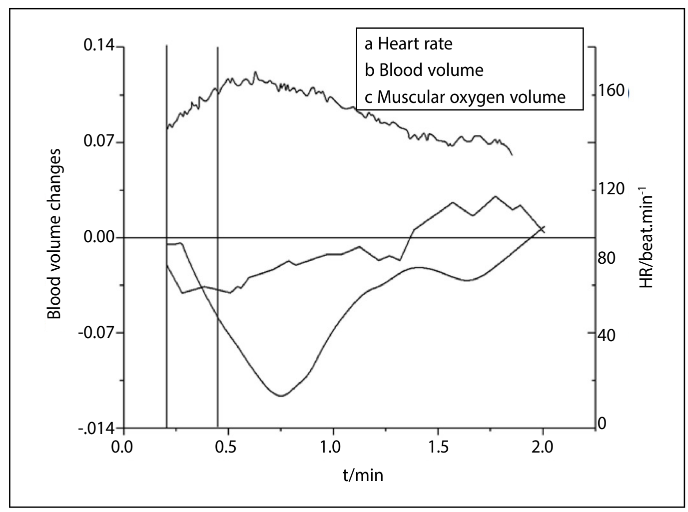

Figure 3. Curve of oxygen saturation and instantaneous heart rate in 100 meters running.

(the time is 15.32 seconds) is between line A and B. At this stage, the muscle oxygen content of the quadriceps had no significant change in the first 7 seconds of the start, but showed a sharp linear decline after 7 seconds. At this stage, the exercise heart rate also showed a linear increase, and the linear slow increase of heart rate began at the start of the run. The right side of line B represents the recovery period after the finish sprint. At this point, the oxygen content in the muscles continues to decline, and the slope has no significant change from that before the finish. The oxygen content continues to recover after 24 seconds and only returns to the state near the start of the race after 2 minutes. At this stage, the heart rate curve is similar to the curve of muscle oxygen content. It is worth noting that: The heart rate peaked about 5 seconds after the finish sprint, and then dropped linearly after 5 seconds. After 1 minute, the heart rate returned to its pre-start level. We believe that when the external load disappeared (at the end of the 100-meter race), the internal load did not disappear, but continued to increase. The reasons for the increase of internal load after the endpoint may be as follows: The rapid increase of external load causes a large velocity difference between the synthesis and decomposition of energy substances in the body, the collected energy is sent rapidly through the heart in the form of blood flow to where it is needed. The greater the speed difference, the greater the amount of energy collected and the faster it is collected. When the external load disappears, the collected energy has no place to send, and its huge impulse has a great impact on the coronary artery, pulmonary circulation system and brain.[10]

CONCLUSION

At present, the number of patients with chronic diseases such as cardiovascular disease is increasing year by year. Sports rehabilitation has become the key to treat cardiovascular disease. Although high-intensity exercise has a good effect on patients with cardiovascular diseases, improper exercise intensity is also easy to increase the risk of cardiovascular diseases. Therefore, we should follow the principle of individualization and choose appropriate exercise intensity according to our own situation to achieve the best effect. Patients with cardiovascular diseases should take lower exercise intensity at the early stage of exercise to avoid sports injury. In the later stage, the exercise intensity can be increased step by step to reduce muscle soreness and improve the rehabilitation effect.

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