EFFECT OF PHYSICAL EXERCISE ON INCREASING THE MAXIMUM OXYGEN UPTAKE OF SKELETAL MUSCLE

O EFEITO DO EXERCÍCIO FÍSICO NO AUMENTO DE CAPTAÇÃO MÁXIMA DE OXIGÊNIO DO MUSCULO ESQUELÉTICO

EL EFECTO DEL EJERCICIO FÍSICO EN EL AUMENTO DE CONSUMO MÁXIMO DE OXÍGENO DEL MÚSCULO ESQUELÉTICO

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ABSTRACT

Introduction: Aerobic exercise can improve the physical function of athletes and increase the oxygen content in skeletal muscles. This has a significant reference value for evaluating training effects and judging sports fatigue. Objective: Maximum oxygen uptake is one of the most critical indicators of aerobic work capacity. The thesis analyzes the medical promotion effect of physical exercise on the oxygen content of skeletal muscle. Methods: The thesis performed aerobic exercises on two groups of young rowers. Athletes in group A performed high-load exercise, and athletes in group B performed low-load exercise. At the same time, we placed a detector on the athletes' skeletal muscle to test the volunteer's muscle oxygen content and other physiological indicators. Results: Comparing high-load exercise and low-load exercise, the maximum oxygen uptake and the utilization rate of the maximum oxygen uptake when reaching the anaerobic net were 10% and 16% higher, respectively. There was no difference in the activity of muscle enzymes between the two groups. Conclusions: After aerobic training, the muscle's oxygen utilization capacity is strengthened. Physical exercise promotes the maximum oxygen uptake of skeletal muscles. ***Level of evidence II; Therapeutic studies - investigation of treatment results.***

Keywords: Exercise; Fasciculation; Biological Oxygen Demand Analysis; Anaerobic Threshold.

RESUMO

Introdução: O exercício aeróbico pode melhorar a função física de atletas e aumentar o conteúdo de oxigênio nos músculos esqueléticos. Isso tem valor referencial importante na avaliação de efeitos do treinamento e no julgamento da fadiga pela prática de esportes. Objetivo: A captação máxima de oxigênio é um dos indicadores cruciais da capacidade aeróbica. A tese analisa o efeito médico de se incentivar exercícios físicos para o conteúdo de oxigênio do músculo esquelético. Métodos: a tese realizou exercícios aeróbicos em dois grupos de jovens remadores. Os atletas do grupo A realizaram exercícios de alta carga; os atletas do grupo B realizaram exercícios de baixa carga. Ao mesmo tempo, colocamos um detector nos músculos esqueléticos dos atletas para testar o conteúdo de oxigênio no músculo e outros indicadores fisiológicos. Resultados: Ao compararmos exercícios de alta carga e de baixa carga, a captação máxima de oxigênio e o índice de utilização de captação máxima de oxigênio ao atingir o ganho aeróbico foram 10% e 16% mais altos, respectivamente. Não houve diferença na atividade de enzimas musculares entre os dois grupos. Conclusões: Após o treino aeróbico, a utilização de oxigênio do músculo se fortalece. O exercício físico promove a máxima captação de oxigênio dos músculos esqueléticos. ***Nível de evidência II; Estudos terapêuticos – investigação de resultados de tratamento.***

Descriptores: *Exercício físico; Fasciculação; Análise da Demanda Biológica de Oxigênio; Limiar Anaeróbio.*

RESUMEN

Introducción: El ejercicio aeróbico puede mejorar la función física de atletas y aumentar el contenido de oxígeno en los músculos esqueléticos. Eso tiene valor referencial importante en la evaluación de efectos del entrenamiento y al juzgar la fatiga por la práctica de deportes. Objetivo: El consumo máximo de oxígeno es uno de los indicadores cruciales de la capacidad aeróbica. La tesis analiza el efecto médico de incentivar ejercicios físicos para el contenido de oxígeno del músculo esquelético. Métodos: La tesis realizó ejercicios aeróbicos en dos grupos de jóvenes remeros. Los atletas del grupo A realizaron ejercicios de alta carga, y los atletas del grupo B realizaron ejercicios de baja carga. Al mismo tiempo, pusimos un detector en los músculos esqueléticos de los atletas para probar el contenido de oxígeno en el músculo y otros indicadores fisiológicos. Resultados: Al comparar ejercicios de alta carga y de baja carga, el consumo máximo de oxígeno y el índice de utilización del consumo máximo de oxígeno al atingir el gano aeróbico fueron 10% y 16% más altos, respectivamente. No hubo diferencia en la actividad de enzimas musculares entre los dos grupos. Conclusiones: Tras el entrenamiento aeróbico, la utilización de oxígeno del músculo se fortalece. El ejercicio físico promueve el máximo consumo de oxígeno de los músculos esqueléticos. ***Nivel de evidencia II; Estudios terapéuticos – investigación de resultados de tratamiento.***

Descriptores: Ejercicio Físico; Fasciculación; Análisis de la Demanda Biológica de Oxígeno; Umbral anaerobio.

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INTRODUCTION

Commonly used test index of anaerobic threshold (AT). Lactic acid is closely related to the dissociation of oxyhemoglobin (HbO_2). The body will experience an imbalance of oxygen supply and demand during heavy exercise. The status of skeletal muscle oxygen supply and consumption is an effective way to understand the status of body functions during exercise. The body's adaptation to different intensities of loads and mastering the training intensity, evaluating training effects, and judging sports fatigue have important reference values. Some scholars have proposed using near-infrared spectroscopy (NIRS) to measure oxygen supply and oxygen consumption in living tissues. Subsequently, some scholars conducted extensive research on the reliability and effectiveness of NIRS in testing muscle oxygen levels during exercise and have been confirmed.[1] In this study, a continuous light three-wavelength system was used to test male juvenile rowers' skeletal muscle oxygen changes during the incremental load process. At the same time, we test the subjects' heart rate (Hb), blood lactate (BLa), and oxygen uptake (VO_2). This article uses NIRS to measure muscle oxygen to assess the feasibility of individual aerobic metabolism.

METHOD

Object

We chose 22 healthy young male rowers from our school's water sports center. We are divided into two groups A and B, according to the level of exercise. Group A is the incredible group (n=12), including 5 first-level athletes and 7 second-level athletes. Group B is the general group (n=10). The professional training years of this group of athletes are less than 2 years. The primary conditions of the subjects are shown in Table 1.

Instruments and equipment

American MAX-II cardiopulmonary function meter, domestic YSI-23L blood lactate analyzer, portable three-wavelength muscle oxygen meter, German WLP-940 power bicycle, Finnish P-Lar heart rate monitor.

Methods and steps

We choose the right lateral femoral muscle to measure muscle oxygen content. In the experiment, the probe was placed longitudinally about 10 cm above the knee joint gap of the subject's right thigh.[2] At the same time, we make the axis of the light source and the detector parallel to the thigh.[3] To prevent the influence of sweating, we put an ultra-thin transparent plastic between the skin and the detector and use a particular shading device to fix the detector on the skin of the detected area. This can avoid the interference of external light.

The experiment adopts a step-by-step increasing load power bicycle exercise. Start the formal test after 2 minutes of preparation activities. The initial load is 50W, 70 rpm, and the increment is 50W every 3 minutes. After the experiment reaches AT, it can be accelerated to 80-90 rpm to exhaustion. During the exercise, the skeletal muscle oxygen content, oxygen uptake (VO_2), and heart rate (HR) were measured at the end of each load level. 10-15 seconds before the end of each load level, we take blood from the fingertips to determine the lactic acid content. Group A completes level 6 load, and group B completes level 5 load.[4]

Table 1. Basic information of subjects.

	Group A (n = 12)	Group B (n = 10)
Age (y)	16.9±0.64	15.2 ±0.48
Height (cm)	184±2.4	182 ±4.14
Weight (kg)	70±1.9	68.5 ±3.0
Training years (y)	2.89±0.64	0.67 ±0.25
Exceptional sports performance (min)	7.56±0.15	8.08 ±0.13

Modeling of personnel travel energy consumption

As early as the beginning of the last century, British scholar Gathcart and others started researching the energy consumption of personnel traveling. In the early 1960s, Goldman et al. studied the energy consumption of weight-bearing travel and obtained a regression model formula for energy consumption and travel speed, load, and rowing slope:

$$\begin{aligned} E &= 4.3+(11V-0.22V^2)+(-6.3G+8.2GV-0.05GV^2+3.6G^2V^2) \\ &+(4.06LG-1.77LGV+0.003LV^2+0.24LGV^2-0.06LG^2V^2) \end{aligned} \quad (1)$$

Where E is energy consumption. V is the travel speed. L is negative weight. G is the rowing slope. They proposed an energy consumption model that includes the metabolic energy consumption of travel speed, slope, weight and body weight, and road coefficient:

$$M=\eta(W_b+L)\{2.3+0.32(V-2.5)^{1.65}+G[0.2+0.07(V-0.5)]\} \quad (2)$$

M is metabolic energy consumption. η is the road coefficient. W_b is the weight. Studies have shown that the applicable range of the model is various situations where the speed is more significant than 2.54km/h, the weight-bearing position is close to the human center of gravity, and the product of the weight and the speed is less than 100. The model for rowing is as follows:

$$\begin{aligned} VO_2 &= 0.248097+0.0032551W_b+ \\ &(0.0443829-0.0010604W_b)V+(0.0005636W_b-0.0144847)V_2 \end{aligned} \quad (3)$$

VO_2 is oxygen consumption. W_b is body weight. V is the travel speed. For the convenience of comparison and application, the experimental research model also uses the power unit watt to represent the metabolic intensity of exercise energy. We apply the commonly used formula for oxygen uptake and power conversion:

$$E=352.38\times(0.23R+0.77)VO_2 \quad (4)$$

E is energy consumption. R is the respiratory volume. VO_2 is the oxygen uptake. Among them, R and VO_2 correspond to each other, they are the average of the R values recorded in the fourth minute of each speed stage. The article establishes a mathematical energy consumption model, and the specific analysis process is as follows:

1. Determine the variables that affect energy consumption (E). The essential variables that determine travel energy consumption are speed (V), gradient (G), and load ratio (L/W_b). However, the relationship between energy consumption and these variables, especially speed, is not a simple linear relationship. At the same time, various variables generally have cross-influences. We get 12 items such as $\upsilon^2, V\times G, V\times\frac{L}{W_b}, G\times\frac{L}{W_b}, (\frac{L}{W_b})^2, (\frac{L}{W_b})^3, V_2\times G, V_2\times\frac{L}{W_b}, V\times G\times\frac{L}{W_b}$ to ensure that the relevant variables are not artificially omitted.
2. Filter variables. We use the backward method to filter out the excess variables, and the standard is α ≥ 0.100. We then use the forward method to select model variables. The selection criteria is α ≥ 0.050. The selected variables are as follows:

$$\begin{aligned} &V^2: \quad F=144.189 \\ &V: \quad F=21.860 \\ &V\times G: \quad F=175.474 \\ &V^2\times\frac{L}{W_b}: \quad F=16.519 \\ &V\times G\times\frac{L}{W_b}: F=164.535 \end{aligned} \quad (5)$$

Data processing

The data are all expressed as mean±standard deviation. We use SPSS10.0 statistical software. The article uses unary regression to analyze the relationship between muscle oxygen and lactate, oxygen uptake, and heart rate.[5] The aerobic capacity of the two groups of athletes was compared by independent-sample t-test, and P<0.05 indicated a significant difference.

RESULTS

Comparison of aerobic exercise capacity of the two groups of athletes

It can be seen from Table 2 that the physiological indicators of the athletes in group A are higher than those in group B (P<0.01). This shows that there are very significant differences in the aerobic exercise capacity of the two groups of athletes.

Muscle oxygen changes during increasing load

Under the encouragement of group A athletes, 10 people completed the 6th load, and 2 athletes completed the 6th load for 2 minutes. In the statistics, we calculate according to the 6-level load. Seven athletes in Group B completed the 5th load, and 3 athletes completed the 5th load for 2 minutes. In the statistics, we all calculate according to the 5-level load. Figure 1 and Figure 2 are typical examples of measured muscle oxygen changes when a rowing athlete in each A and B group completes the 6th and 5th load.[6] The relative change of oxygenated hemoglobin content (HbO_2) in the figure represents the change of muscle oxygen.

In Figures 1 and 2, the abscissa is time.[7]

The relationship between end-load muscle oxygen density and lactate, oxygen uptake, and heart rate

It can be seen from Table 3 that when the athletes in Group A increase their load, the decrease in muscle oxygen content is synchronized with the increase in lactate, oxygen uptake, and heart rate. Statistical analysis showed that muscle oxygen was highly negatively correlated with lactate, oxygen uptake, and heart rate.

From Table 4, the decrease in muscle oxygen content of the athletes in group B increases in synchronization with the increase in lactate, oxygen uptake, and heart rate.

Table 2. Comparison of aerobic exercise performance indexes of athletes in groups A and B.

	Group A (n = 12)	Group B (n = 10)
VO_2max (ml/ kg/ min)	62.73 ±4.87	54.63±3.34
VO_2max (ml/ min)	4318.30±406.16	3737.71±240.56
LT (%VO_2max)	66.90 ±3.7	62.73±3.51
VT (%VO_2max)	69.73 ±8.52	57.08±4.98

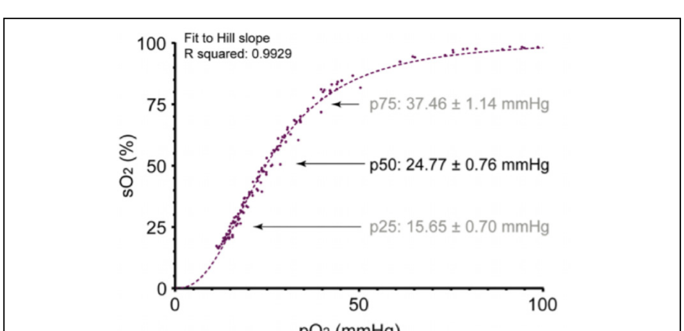

Figure 1. Muscle oxygen changes of a rowing athlete in group A during the 6-level load exercise.

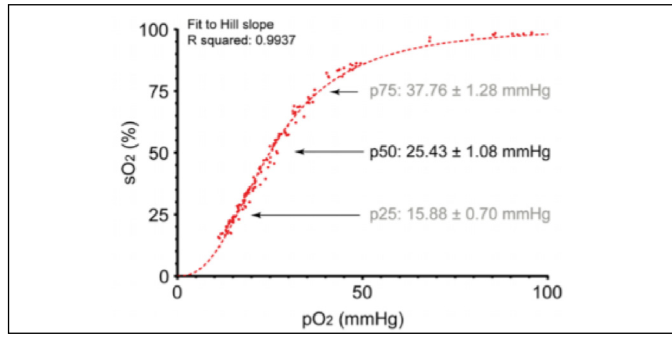

Figure 2. Muscle oxygen changes of a rowing athlete in Group B during the 5-level load exercise.

Table 3. Muscle oxygen, lactate, oxygen uptake, and heart rate test results of athletes in group A during incremental exercise.

	Muscle oxygen (Δμmol/L)	Oxygen uptake (ml/min)	Heart rate (b/min)	Lactic acid (mmol/L)
Class 1 load (50W)	-24.67±15.36	1058.5±162.9	97.2±6.7	1.77±0.02
Class 2 load (100W)	-51.0±24.6	1812±184.39	106.2±10.64	1.98±0.16
Class 3 load (150W)	-80.5±21.51	2399.4±151.02	133.6±8.38	2.4±0.65
Class 4 load (200W)	-98.40±21.04	2919.4±176.58	158.2±6.22	3.26±1.16
Level 5 load (250W)	-162.0±43.67	3789.4±168.83	177.2±7.12	8.24±1.94
Class 6 load (300W)	-188.0±41.92	4454.6±312.68	189.2±6.22	13.54±3.24

Table 4. Muscle oxygen, lactate, oxygen uptake, and heart rate test results of athletes in group B during incremental exercise.

	Muscle oxygen (Δμmol/L)	Oxygen uptake (ml/min)	Heart rate (b/min)	Lactic acid (mmol/L)
Class 1 load (50W)	-25.2±15.81	950.57±89.62	101.14±8.63	1.8±0.64
Class 2 load (100W)	-63.0±23.92	1587.28±190.26	113.83±10.38	2.9±1.04
Class 3 load (150W)	-123.4±38.02	2282±251.17	142±9.02	3.64±1.32
Class 4 load (200W)	-271.0±73.61	3083±246.98	160.2±9.26	7.69±2.38
Level 5 load (250W)	-277.00±87.72	3765.57±259.67	177.33±6.65	11.01±3.99

DISCUSSION

The relationship between muscle oxygen changes and oxygen uptake

This experiment shows that the change in muscle oxygen at the end of each level is highly negatively correlated with oxygen uptake. Peripheral muscle oxygen dynamics reflect system oxygen uptake. The study found that the delay time of oxygen uptake (30±8s) was significantly longer than the delay time of deoxygenation (10±3s). The local oxygen ionization increases faster than the oxygen uptake. On the contrary, increased local perfusion and increased oxygen delivery do not match the metabolic tissue rate. This shows that the increase in the body's oxygen consumption increases the body's demand for oxygen, and then the oxygen uptake increases.

The relationship between muscle oxygen changes and blood lactate changes

In this experiment, the change in muscle oxygen at the end of each load level was highly negatively correlated with blood lactate. The slight decrease of muscle oxygen at a low load is consistent with the slow increase of lactate. When the load is large, the muscle oxygen drops rapidly, and an inflection point appears, which is consistent with the inflection point of the increase of lactic acid. Some scholars believe that when the exercise intensity is high, various acidic metabolites inside and outside the muscle cells increase, lactic acid begins to accumulate, and the increase of $PaCO_2$ and H^+ concentration promotes the rapid separation of O_2 and hemoglobin. Therefore, reduced hemoglobin increases, and oxygenated hemoglobin decreases. Some scholars have found in experiments that the femoral venous oxygen partial pressure (PaO_2) has only a tiny change from moderate-intensity to high-intensity exercise. Still, the oxygen capacity decreases significantly with the increase in intensity.[8]

CONCLUSION

The muscle oxygen content of skeletal muscle decreases stepwise during incremental exercise. Muscle oxygen decreases rapidly when the load is low and then maintains balance or increases. Muscle oxygen continued to decrease when the load was high, and there was an overrecovery phenomenon after the exercise stopped. Muscle oxygen content is negatively correlated with oxygen uptake, heart rate, and lactate.

All authors declare no potential conflict of interest related to this article

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