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Metabolism system during exercise and its guiding value for exercise

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Abstract. With the development of today's society, people's daily activities are becoming increasingly diverse, and sports are gradually integrated into people's daily lives. However, there are still biases and misunderstandings in social cognition regarding physiological knowledge of sports. Therefore, this paper aims to study the energy metabolism response during exercise, focusing on the metabolic mode of cellular respiration and providing guidance on exercise from this study. With the deepening of research, it can be understood the relationship between ATP and energy, recognized that the body generates ATP through three metabolism ways: glycolysis, ATP-PCR, and cellular respiration, and understood the differences between these three metabolism ways, also recognizing that they are crucial for the development of athlete performance. Finally, this paper will provide a method for athletes to train their metabolism system that combines long-term steady-state training with interval training.

Keywords: metabolism system, cellular respiration, ATP, glycolysis, Kreb's cycle.

1. Introduction

In daily activities, the human body requires a continuous energy supply to function. This energy need changes with changes in activities, and exercise places unique demands on the body's ability to provide energy. ATP is an important substance involved in energy metabolism in the body and participates in countless cellular reactions. Metabolism refers to the process by which all chemical reactions occur in the body to maintain activities. These chemical reactions will convert carbohydrate, fat, protein, and other nutrients from food into human Chemical energy and discharge metabolic waste. ATP is also the main form of energy storage in the human body. The metabolism system uses energy to synthesize ATP for activity, which breaks high-energy bonds when the human body needs energy to release energy and complete actions. At a certain time, the storage capacity of ATP in the human body is very limited. The ATP content of muscle cells is enough for only 3 seconds of intense exercise, and the total ATP stores of the body are enough for only a few minutes. This means that human activities require the metabolic system to work to continuously synthesize ATP and generate energy. This article will investigate how ATP participates in the energy metabolism system and focus on how ATP participates in cellular respiration and supports body activities. These mechanisms may provide valuable references for the training of the energy metabolism system that may be used by athletes.

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2. Overview of ATP

The energy contained in food is stored within molecular bonds, which connect carbon and other elements in various ways to form carbohydrates, proteins, and fat molecules. After the human body ingests these nutrients, the molecular bonds are split and recombined countless times in the metabolic process and finally form the adenosine triphosphate molecule, which is usually called ATP. During this process, the energy contained in food is transformed into the Chemical energy of the human body and stored in ATP.

To better understand the mechanism of ATP energy supply, the following will explain the concise structure of ATP. ATP is composed of five elements: carbon, hydrogen, oxygen, nitrogen, and phosphorus. Each ATP molecule has 3 phosphoryl (phosphate) groups,1 adenine and 1 ribose. A large amount of energy is stored in the chemical bond linking the phosphate groups, so this Chemical bond is also called the high energy bond. The Chemical energy that supplies energy for human mechanical movement is essentially the bond energy stored in the high energy bond. When the body needs energy, the bond between the 2nd and 3rd phosphate groups will break and release energy to provide 'fuel' for activities.

The following content will analyze the importance of ATP in human activities at a microlevel. Human activities must be accompanied by muscle movement. At the micro level, the mechanism of muscle contraction has been determined by the theory of sliding filaments [1]. During this process, ATP is closely involved. The myosin head needs ATP to attach the actin and form the cross-bridge. When the muscles contract, more cross-bridges need to be formed, so the myosin head needs to crawl to the next binding site along the actin. After the myosin head releases the actin, ATP breaks the chemical bond to release the energy to cock the myosin head into a high energy conformation, and ATP turns into ADP. And then, the phosphate groups isolated due to fracture will be released and push the myosin head to attach the next binding site on the actin, and at the end of the process, ADP will be released from the myosin head and join the metabolism to become ATP again. Both muscle relaxation and contraction require ATP.

3. Metabolism systems

The metabolism systems of the human body are divided into two categories based on whether oxygen is involved in the metabolism: the anaerobic system and the aerobic system.

The anaerobic system includes two ways of synthesizing ATP: one is Glycolysis, and the other is from the reaction of phosphocreatine and ADP. The aerobic system involves Krebs' cycle and the electron transport chain. Next, we will discuss these physiological processes one by one.

First, this chapter will talk about the metabolism of the anaerobic system. The first way of synthesizing ATP is called glycolysis. This process occurs in the cytoplasm. In glycolysis, glucose with six carbons is decomposed into two pyruvates with three carbons each and generates two molecules of ATP. (During the Glycolysis process, two molecules of ATP are required to supply energy for the reaction, and eventually four molecules of ATP are generated, which means two molecules of net ATP are generated in the whole process). Simultaneously two molecules of NAD+ (coenzyme of dehydrogenase) are reduced to two molecules of NADH (chemical elements in mitochondria) [2]. When the oxygen intake of the body is insufficient, pyruvate will be converted into lactate under anaerobic conditions, and the rise of the level of lactate in the body is the reason for feeling sore during exercise, which is also known as acidosis [3].

Another pathway for ATP generation in anaerobic systems is relatively simple. The body obtains amino acids through proteins, and then the amino acids react to generate phosphocreatine, and then the phosphocreatine breaks the Chemical bond to separate the phosphate group and combines with ADP, which reuses ADP to generate ATP.

Next section will focus on the metabolic process of the aerobic system, also known as cellular respiration. Unlike anaerobic systems that utilize the singularity of nutrients, cellular respiration can utilize the three major organic nutrients for energy metabolism, which indicates that the ATP synthesis efficiency of aerobic systems is higher than that of anaerobic systems [4]. In fact, glycolysis is the first step of cell respiration, but since glycolysis does not involve the intake of oxygen, glycolysis is classified

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as an anaerobic system. After glycolysis, pyruvate is ready for cellular respiration. To better understand the process of cell respiration, the chemical structure of pyruvate will be briefly introduced below. Each Pyruvic acid contains a acetyl group and one carboxyl group. The acetyl group contains two carbons, three hydrogens, and one oxygen, and the carboxyl group contains one carbon and two oxygens. Pyruvate will react with coenzyme A. During this reaction, the carboxyl group will be isolated and become carbon dioxide, which will be discharged, and the acetyl group will attach to the coenzyme A and generate acetyl CoA. At the same time, one molecule of NAD+ will combine with the hydrogen in coenzyme A to reduce it to NADH.

Then, acetyl CoA enters the chemical reaction called Kreb's cycle (also called the citric acid cycle). First, acetyl-CoA generates citric acid through a reaction, and then citric acid generates Oxaloacetic acid through a series of reactions in Kreb's cycle. In this series of reactions, three molecules of NAD+ are converted into NADH, one molecule of FAD is converted into FADH, one molecule of Q is converted into QH2, and one molecule of ATP is generated. Then Oxaloacetic acid can generate citric acid again through a chemical reaction and enter the reaction cycle [5].

After Kreb's cycle generates a series of substances, these substances (NADH, QH2) will enter the electron transport chain (ETC) and combine with the oxygen ingested to oxidize and generate a large amount of ATP, which is also the main process of generating ATP in the process of cell respiration [6]. When calculating the amount of metabolites, it should be noted that one molecule of glucose can be decomposed into two molecules of pyruvate, so the amount of products in cell respiration needs to be calculated twice. In the reaction of ETC, one molecule of NADH can generate 2-3 molecules of ATP, and one molecule of QH2 can generate 1.5-2 molecules of ATP. Through calculation, we can know that 25-36 molecules of ATP can be generated in the process of cell respiration (excluding glycolysis), which is far more than that of an anaerobic system.

4. The role and coordination of the metabolism system in exercise

When the anaerobic and aerobic systems function, they are not independent, but rather determined by the type of exercise that determines which metabolism system dominates the energy supply. At every node, aerobic and anaerobic systems operate simultaneously and coordinate with each other.

At rest, the body mainly metabolizes glucose and fat in the body to provide energy for the body through cellular respiration. The main metabolic waste products produced by cell respiration are water and carbon dioxide, which the body can easily expel. Moreover, fat storage efficiency is high, and breaking down one molecule of fat can provide twice the energy of protein and glucose. The energy required to decompose protein is higher than that of fat and glucose. So, protein, as the body's final energy reserve, is generally not easily utilized.

When exercise begins, athletes' muscles must rapidly increase the rate of ATP production to ensure that the body's energy supply can meet the transition from rest to exercise. At this stage, ATP stored in muscles and ATP-PCR are mainly used for energy supply, and the metabolic rate of glycolysis and cellular respiration is also gradually rising. About the twentieth second of exercise, the rate of glycolysis energy supply reaches its highest and replaces ATP-PCR as the main way of energy supply. Within the following one to four minutes, the body's oxygen intake rapidly increases and stabilizes, followed by cellular respiration becoming the main energy supply mode.

During exercise, lactate is continuously generated and cleared with sufficient oxygen. When the rate of lactate production exceeds the cleared rate, it will overflow into the blood and cause obvious fatigue, which is called the lactate threshold. When the lactate threshold is reached, it means that the oxygen intake by the body gradually fails to meet the energy demand. As the intensity of exercise continues to increase and the oxygen supply no longer meets the energy demand, the anaerobic threshold is reached, and the recovered anaerobic metabolic system once again dominates the energy supply [7].

5. Exercise recommendations based on metabolism system

Based on the metabolism system, the following will provide suggestions for improving exercise performance by targeting the metabolism system. The first is nutrition intake. In addition to ensuring

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adequate nutrition intake at ordinary times, three nutrients can also be taken before exercise to improve glycogen storage level and phosphocreatine content in the body, so that ATP-PCR and glycolysis can have sufficient metabolic materials to improve the performance of explosive exercise.

The second is about the improvement of cardiopulmonary adaptation and energy supply ability.

A better training method for improving metabolism ability is to combine long-term steady-state training with intermittent training during fluctuation cycles. Long term steady state training can maximize cardiopulmonary adaptation and VO2 max [8]. This training method mainly challenges the maximum aerobic ability to enable the body to adapt to the new anaerobic threshold. After a period of long term and sub maximum intensity steady-state training, the metabolism system can form a constantly improving adaptation and ultimately obtain stronger aerobic ability.

Intermittent training achieves a higher intensity of work by providing recovery time between each repeated training session. This type is designed to allow the energy supply system in the explosive mode of the metabolism system to have sufficient recovery time between each repetition, thereby improving explosive power and explosive endurance, while also improving exercise performance after anaerobic threshold. It is recommended that experienced athletes carry out high-intensity interval training (HIIT) to force the body to approach the limit in each round of repeated training, thus posing greater challenges to the energy metabolism system [9]. HIIT can induce rapid and profound patterning of mitochondrial content and enzyme activity. This training specifically targets metabolic capacity and energy producing cellular pathways, and fully strengthens type 2 muscle fibers. At the same time, intermittent training modes can enable mitochondria to better oxygenate fatty acids and reduce fatigue caused by lactate accumulation [10].

Athletes can alternate between two training modes according to their own training needs. Below is a more general guide. Athletes can engage in medium to low intensity and long-term steady-state training on the first day to put their bodies into motion and provide an aerobic foundation. At the same time, this day serves as a recovery day after high-intensity training to prevent overtraining. On the second day, engage in submaximal intensity and long-term steady-state training to enable the body's aerobic capacity to adapt to higher exercise intensity and prepare for high-intensity training. On the third day, HIIT is performed to adapt the body to a high-intensity and efficient metabolic mode. It should be noted that the rest time during high-intensity training should be two to three times the exercise time for individuals to fully recover and prevent overtraining.

6. Conclusion

The metabolism system is crucial for exercise. The body converts nutrients into ATP through the metabolic system to store energy in the body. When exercise occurs, the body uses ATP to provide energy. This study investigates how the body synthesizes ATP through the metabolism system to provide energy for bodily activities and provides a detailed explanation of how the body generates ATP through three ways: glycolysis, ATP-PCR, and cellular respiration. At the same time, these three metabolism modes work together and coordinate with each other to continuously provide energy to the body during exercise, and which metabolism mode dominates the energy supply depends on the type of exercise. Therefore, a combination of long-term steady-state training and interval training is proposed to comprehensively train the metabolism system of athletes. This article comprehensively researches the mechanisms of the metabolism system through literature analysis, but some conclusions are not keeping up with the times, so research on metabolism is not yet comprehensive.

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