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Review article

Anaerobic threshold employed on exercise training prescription and performance assessment for laboratory rodents: A short review

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ABSTRACT

Several studies have generated numerous terms in the field of exercise training prescription and performance assessment that often do not match the information previously demonstrated by many other works, generating much debate and resulting in an immense pool of scientific results. Several protocols in exercise training prescription and performance assessment have been proposed for these purposes by many reasons. In the field of exercise science, the protocol must be thoroughly investigated and provide real tools to be reproducible. Many laboratories have been adapting and developing evaluation protocols and testing on physical training of rodents in different experimental conditions. In this context, mice, rats and rabbits are preferentially chosen due to easy manipulation and good response to exercise, and comparable at results obtained with humans in compatible effort intensities. But, the exercise training programs and aerobic-anaerobic transition assessment proposed for animal models vary extensively, depending on the species, gender, age, type of stimulus, type of exercise, type of method and also on the specific objectives of the program. This short review demonstrates the need in offering tools performed by invasive measurement to assess the anaerobic threshold by blood lactate employed on evolution of aerobic-anaerobic parameters of rodents. The objective of this short review was to present and to discuss physical evaluation protocols applications to rodents. The table submitted may give a basis for anaerobic threshold employed on exercise training prescription and performance assessment for laboratory rodents in future research.

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1. Introduction

The determination of aerobic-anaerobic transition performed by invasive methods of anaerobic threshold (blood lactate) has great importance to some related areas, such as performance assessment and training prescription for humans and laboratory rodents. In this context,

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an intense debate emerged in the scientific field, which was mainly based on concept of anaerobic threshold [19, 28, 35, 66, 107].

The term or concept of "anaerobic threshold" it may be to replace to a more functional description, since the skeletal muscle are never entirely aerobic or anaerobic. In this situation, the blood lactate during moderate-intense exercise plays a major role as a metabolic substrate during aerobic-anaerobic transition in muscle contraction, once that is the preferred fuel for slow-twitch skeletal muscle fibers (oxidative fiber type), and is a precursor for liver gluconeogenesis. This theory has been challenged during the last decades. Thus, when the blood lactate begins to accumulate, promotes an increase in cardiopulmonary demand and physiologic changes in the organism. These include metabolic acidosis, diminished skeletal muscle contraction, increase of ventilation, and altered oxygen kinetics, all of which contribute to an impaired capacity to perform work [19, 28, 30, 35, 45, 64, 65, 67, 80, 105].

Thus, the underlying mechanism that describes the process and the physiologic changes associated with blood lactate accumulation may add important information about exercise training concerning the efficacy of the strategic intervention for performance. The published evidences are available demonstrating that blood lactate accumulation occurs later after a period of intense endurance training. In athletes, the level of skeletal muscle contraction that can be sustained prior to lactate accumulation is an accurate predictor of increase endurance performance [19, 28, 35, 65, 105].

In addition to protocols with humans, an interesting tool to study the physical performance by invasive methods is the use of experimental animal models (rats, mice and rabbit). The protocols are designed to simulate the exercise training promoting changes metabolic, mechanical and cardiopulmonary responses [18, 69, 71, 81]. Concerning the anaerobic training protocols, many studies have used swimming or efforts with jumps performed in water [56, 86] platforms through electric stimulation [4, 93], and protocols with different nutritional and pathological conditions [2].

In this context of protocols exercise training to rodents, the treadmill running is a common method of training used by researchers to investigating physiological adaptations produced by acute or chronic physical activity [57, 72, 97, 107]. Thus, the standardization of assessment protocols is important to determine an efficient exercise training program to rats, mice and rabbit [36, 57, 61].

Among several exercise regimens used for improving performance, such as treadmill, swimming and platforms with electric stimulation, the exercise training in particular has been associated with several metabolic and cardiovascular benefits [15, 44, 96]. As a consequence, a large number of investigations resulted in different protocols for identification of metabolic initial aerobic-anaerobic transition zone by invasive methods in humans and animals models. Thus, to be useful, the method must be reproducible and must identify the threshold with some accuracy [28]. Each method of prescribing relative exercise intensity has both advantages and disadvantages when both theoretical and practical considerations are taken into account.

The present short review demonstrates the need in offering tools performed by invasive measurement to assess the anaerobic threshold by blood lactate employed on evolution of aerobic-anaerobic performance of animals involved in experiments, where physical training is approached as physiological condition. The objective of this short review was to present and to discuss physical evaluation protocols applications to rodents. The table submitted in this short review may give a basis for anaerobic threshold (aerobic-anaerobic transition) employed on exercise training prescription and performance assessment for laboratory rodents in future research.

2. Methodological concepts

Concepts employed on exercise training prescription and performance assessment based in anaerobic threshold it has generated intensive debates between researchers. The lack of consensus among several works of researchers stems not only from the absence of methodological standardization but also from a lack of consensus on the theoretical basis of the concept itself. Efforts to accurately describe the prescription of exercise training and performance assessment have resulted in an immense pool of scientific data. Resulting in disagreement among concepts for the definition of anaerobic threshold that persists for decades [14, 28, 83, 89, 91].

According to a widely accepted theory, the anaerobic threshold refers to the raise in plasma lactate concentration, which develops in two steps (first and second ventilatory threshold). This term is due to compensation for insufficient aerobic metabolism by anaerobic glycolysis, with accumulation of lactate resulting in a decrease of performance and skeletal muscle contraction and consequently fatigue. Because of this lactate accumulation and low pH, great importance has been placed on this model of prescription and investigation of performance training [3, 14, 83, 89, 91, 102]. We argue that this importance is excessive and these variables should be used with caution in the interpretation of experimental and clinical exercise testing: (a) there is no enough evidences on aerobic system impaired above first ventilatory threshold and, thus, there is no evidence of an anaerobic threshold in this step; (b) the increase in plasma lactate does not reflect anaerobiosis but is the marker of increase of mitochondrial respiration and pulmonary hyperventilation [3, 14, 28, 83, 89, 91, 102].

In this context, the intensity of exercise plays an important role, or to most important tool to exercise training prescription and performance assessment for many authors. Can be related to a percentage of maximal exercise capacity, maximal heart rate or linked to the concept of the so-called "lactate threshold". In this way, in exercise physiology, basically two different methods are used for the determination of the anaerobic threshold: Firstly (a) direct, invasive measurement of blood lactate, or (b) indirect, measurement of the ventilatory and gas exchange response. These differences in the methodological approach have led to a contradictory nomenclature and controversy on the physiological basis of what is called the lactate threshold or anaerobic threshold and even more confusion and misunderstandings prevail concerning the non-invasive determination of the lactate threshold via changes of ventilation and gas exchange parameters during exercise [19, 42, 45, 65, 89, 100, 105].

3. Historical remarks on aerobic-anaerobic transition

Initially, the term acid lactic began in 1808 with Berzelius's discovery of an elevated concentration of lactate in the muscle of hunted stags [35]. After this period, several studies was realized, suggesting that glycogen was the precursor of lactate, thus, your depletion can lead to impaired muscle function.

Hill [46] coined the term "maximum oxygen consumption" in exercise, which was the first most common mean of evaluating aerobic endurance capacity in individuals. These discoveries changed the field of muscle energetics profoundly, period called "the revolution in muscle physiology". Years later, Hollmann [47] established the so-called "point of optimum ventilator efficiency" corresponding to the first increase in the ventilatory equivalent of oxygen and of arterial lactate concentrations during incremental exercise. This concept was very important for establish a sub-maximal parameters to assess aerobic performance fitness in patients and athletes.

In such sense, after development the enzymatic techniques in blood, numerous lactate threshold concepts were developed by researchers that increased popularity of methods employed on exercise training prescription and performance assessment in laboratory [3, 83, 104]. However, as previously mentioned, the variety of different anaerobic threshold concepts has led to considerable confusion and misinterpretation between scientific works. Of interest to researchers and clinicians, the increase of lactate in response to intensity of endurance exercise it has been the subject of extensive discussions. But, firstly, what's