MLS - SPORT RESEARCH

https://www.mlsjournals.com/Sport-Research

How to cite this article:

Lecuona Martínez, D., Corbo Borsani, J. M. & Ramírez Carrasco, C. (2021). Saturación de oxígeno y test de lactato en ciclistas. *MLS Sport Research, 1*(2), 19-32. doi: 10.54716/mlssr.v1i2.673

OXYGEN SATURATION AND LACTATE TEST WITH CYCLISTS

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Abstract. This study aims to determine if the Humon Hex device used to measure SmO2 can be used as an equivalent to the lactate test. Studying whether the potency of the lactate threshold can be established by changes in SmO2. The objective is to compare the blood lactate concentration and the SmO2 measurement to predict the lactate threshold power during the performance of a progressive exercise test in trained cyclists. During the power increases, it is observed that the% SmO2 decreases, and the Lactate concentration increases. Through Pearson's correlation analysis, a strong inverse correlation is evidenced between the variables studied. It is observed that SmO2, both at the basal level and at the lactate threshold, presents a wide dispersion of its values that limits its usefulness, and we were unable to find a standard absolute threshold value for all the subjects in the sample. Comparing the threshold lactate power estimated by the lactate concentration in the blood, and the algorithm of the Humon Hex software gives an average difference of 13w ± 18.5, and an average time difference of 87" ± 27.5. Although the n of the sample is low, this data is promising to apply the Humon Hex as an indirect estimation tool of the lactate threshold of daily training.

Keywords: training, intensity, lactate, lactate threshold, SmO2

SATURACIÓN DE OXÍGENO Y TEST DE LACTATO EN CICLISTAS

Resumen. En este estudio se pretende determinar si el dispositivo Humon Hex empleado para medir la SmO2, puede usarse en forma equivalente al test de lactato. Estudiando si la potencia del umbral de lactato se puede establecer mediante los cambios de la SmO2. El objetivo es comparar la concentración de lactato en sangre, y la medida de SmO2 para predecir la potencia de umbral de lactato durante la ejecución de una prueba de esfuerzo progresivo en ciclistas entrenados. Durante los incrementos de potencia se observa que disminuye el % SmO2, y la concentración de Lactato aumenta. A través del análisis de correlación de Pearson se evidencia una correlación inversa fuerte entre las variables estudiadas. Se observa que la SmO2 tanto a nivel basal como en el umbral de lactato, presenta una amplia dispersión de sus valores que limita su utilidad, y no se logra encontrar un valor umbral absoluto estándar para todos los sujetos de la muestra. Al comparar la potencia umbral de lactato estimada por la concentración de lactato en sangre, y el algoritmo del software del Humon Hex da una diferencia promedio de 13w ± 18,5, y una diferencia de tiempo promedio de 87´´± 27,5. Si bien el n de la muestra es bajo estos datos son prometedores para aplicar el Humon Hex como una herramienta de estimación indirecta del umbral del lactato del entrenamiento diario.

Palabras clave*:* entrenamiento, intensidad, lactato, umbral de lactato, SmO2

Introduction

In the planning of endurance training, it is necessary to know the training zones, that is, the intensity of exercise according to the objective of the session. Blood lactate concentration is an indirect measure used for intensity control (Brooks, 2020; Rodriguez et al., 2019), it is a reference parameter used to determine the intensity levels in training planning. The measurement of muscle oxygen saturation (SmO2) is a new method that through the technique of near-infrared spectroscopy (NIRS) non-invasively determines changes in tissue oxygenation in athletes performing incremental exercise (Racinais et al., 2014). While the assessment of the lactate test indicates systemic changes and is invasive, with muscle oxygen saturation we obtain a continuous and non-invasive assessment of what happens in the muscle against the effort.

The present study aims to answer whether a NIRS device that measures SmO2 can be used in an equivalent way to the lactate test in the indirect determination of intensity. The relevance of the topic is given that the device used to measure muscle oxygen saturation is portable and non-invasive compared to the lactate test. In order to validate the use of an indirect measurement tool to estimate the lactate threshold and thus identify the training zones, determine the intensity levels that serve as inputs in the planning and dosing of loads. The objective is to compare the blood lactate concentration and the SmO2 measurement to predict the lactate threshold power during the execution of a progressive effort test in trained cyclists. During the execution of the test, the % of SmO2 of the vastus externus and the lactate concentration are recorded. The relationship between muscular oxygen saturation with power and lactate concentration with power is analyzed during the test. The theoretical support of the work is addressed in the theoretical framework; chapter 1: refers to cycling and science in the development of science and technology applied to the efficiency of sports performance; chapter 2: sports training specifically oriented to cycling, and the intensity as one of the significant variables in terms of the organization of stimuli in terms of performance objectives; chapter 3: metabolism, processes, and substrates; chapter 4: defines lactic acid, lactate, lactate test, and lactate threshold as an indicator of aerobic and anaerobic transition zones; chapter 5: muscle oxygen saturation and near infrared spectroscopy (NIRS), and the Humon Hex device as the new portable technology (NIRS) that in this study is used to indirectly determine lactate threshold, according to muscle oxygen levels.

Near-Infrared Spectroscopy NIRS

Near-infrared spectroscopy (NIRS) is a technology used in different fields of study such as agriculture, cardiology, neurology, and sports sciences, among others (Pino Ortega et al., 2019). Near-infrared spectroscopy (NIRS) oxygenation measurements reflect O2 supply and utilization in muscle exercise and can improve the detection of a critical exercise threshold (Van Der Zwaard et al., 2016). NIRS is used in sport to measure muscle oxygenation during physical exercise in real time using infrared beams, light emitters, or laser diodes with wavelengths in the range of 700-850nm2 and NIRS detectors (Ferrari et al., 2011). It was first commercialized in 1996 (Hitachi Co. Ltd.) basically to display brain activity in neurology (Ferrari & Quaresima, 2012). Oxygen is transported by hemoglobin through the body and varies depending on the intensity of physical activity by a decrease in pH and increase in temperature. SmO2 variations during the course of exercise are related to the relationship between O2 availability in blood and its use in muscles. With NIRS it is possible to estimate SmO2, i.e. the ratio of oxy-hemoglobin to total hemoglobin in the blood, expressed as a percentage.

NIRS Advantages

The data obtained, through a non-invasive technique, are on the kinetics of oxygen saturation in muscle using light emissions and NIRS detectors, which can reach a depth of 4-5 cm deep. Oxygen (O2) is transported in the blood by hemoglobin and by myoglobin in the muscle, and during exercise its levels vary before an intense stimulus oxygen decreases. SmO2 changes depend on the balance between the oxygen available in the blood and its use by the muscle, the % of SmO2 is the ratio of oxy-hemoglobin to total hemoglobin in the blood. With NIRS it is possible to monitor changes in muscle tissue O2 reserves and O2 availability at the cellular level. It is a technique that takes into account the fact that biological tissues are transparent to infrared light and can be used to measure up to 8 cm depth. And considering that the absorption of light in muscle tissue depends on the degree of oxygenation, then the different levels of absorption will indicate the % of SmO2 during exercise. They are portable devices, which can be used during training with real-time monitoring via wireless technology. According to the publication, Monitoring muscles to improve athletic training of the Massachusetts Institute of Technology news office (Winn, 2018), the Humon Hex arises as an idea of a class project at the Sloan School of Management of the Massachusetts Institute of Technology of two students, Daniel Wiese, student of technology and innovation while pursuing his doctorate in mechanical engineering, and Alessandro Babini, a master's degree in management studies. They received support from the Martin Trust Center for MIT Entrepreneurship. Near-infrared spectroscopy, the core technology behind Hex, is a lightweight device that attaches to a user's thigh to determine oxygen levels in muscles by emitting light into muscle tissue and measuring its absorption. That information is then transmitted to a user's phone, smartwatch, or laptop via Bluetooth or ANT+ technology and displayed in a simple graph along with personalized information. As athletes train, the graph shows them whether their muscles are consuming oxygen at a higher rate than they're being supplied, which tells them whether their current pace is sustainable. In another Fast Company article (Schulte, 2019): Why NBA athletes are using this device to improve their training, it is noted that the success of the Hex is that it tracks muscle performance in real time. When oxygen enters the blood through the lungs, it binds to hemoglobin in the cells and turns bright red. After the oxygen is transported and used by the muscles, the blood turns dark blue-red. The Hex interprets how well the muscles are working based on the color of the blood. Moxzones is the app to measure SmO2, distance, time, pace, speed, and much more in real time The app is available for smartphone and Android, and it works in conjunction with the web platform. The hexagon illuminates the muscle with red and infrared light, then four evenly spaced sensors read the amount of light passing through the muscle and how much is absorbed. Bright red, oxygenated blood will absorb more infrared light and allow red light to pass through, while oxygen-poor, blue-red blood will absorb more red light and allow infrared light to pass through. The Hex measures oxygen levels in an athlete's thigh muscle over the course of a workout and, using proprietary software, generates colored graphs showing whether the user's muscles are consuming oxygen at a sustainable (green), unsustainable (red), borderline (orange), or low (blue) rate.

Lactate

Most evidence suggests that lactate is an important intermediate in numerous metabolic processes, a particularly mobile fuel for aerobic metabolism and perhaps a mediator of the redox state between various compartments both within and between cells (Brooks, 2020). Traditionally lactate measurement in training is used to manage different intensities in sports planning, the relationship between lactate and exercise has been the subject of study for over 200 years. Changes in exercise intensity and duration significantly affect lactate concentration (San-Millán, 2020). The production of lactate does not cause acidosis but delays it; every time ATP is broken down into ADP and P(i), a proton is released. When the ATP demand of muscle contraction is met by mitochondrial respiration, there is no accumulation of protons in the cell, as the mitochondria use the protons for oxidative phosphorylation and to maintain the proton gradient in the intermembrane space. Only when exercise intensity increases beyond steady state is there a need for increased reliance on ATP regeneration from glycolysis and the phosphagen system. ATP supplied from these non-mitochondrial sources and ultimately used to drive muscle contraction increases proton release and causes the acidosis of intense exercise. It is with the production of lactate that the NAD(+) needed in phase 2 of glycolysis is achieved. Increased lactate production therefore coincides with cellular acidosis and remains a good indirect marker of the cellular metabolic conditions that induce metabolic acidosis. Lactate acts by reducing acidity because it consumes H+ when very high intensities are developed and maintained over time. H+ production exceeds the buffering system producing a decrease in pH. Stored intramuscular glycogen provides energy, during intense exercise, to phosphorylate ADP during anaerobic glycolysis; in the absence of oxygen supply to accept hydrogen, pyruvate is converted to lactate. Lactate is formed even under resting conditions which is removed by cardiac and skeletal muscles, but when production exceeds the rate of removal under intense exercise its production accumulates. Blood lactate begins to increase exponentially around 55% of maximal aerobic capacity for an untrained healthy person. The increase in lactate concentration during exercise is relative tissue hypoxia (oxygen deprivation). With oxygen deprivation, anaerobic glycolysis meets energy needs and the release of hydrogen ions begin to exceed their oxidation in the respiratory chain. Traditionally, lactate measurement in training is used to manage different intensities in sports planning, the relationship between lactate and exercise has been the subject of study for over 200 years. Changes in exercise intensity and duration significantly affect lactate concentration (Beneke et al., 2011). The lactate test consists of obtaining a measure of lactate concentration from a blood sample taken by finger or earlobe prick and placed in a lactate analyzer. The normal blood lactate concentrations considered since the second half of the 20th century were 0.8 to 2mM/l, while inside the cell it can vary from 1 to 1.8 mM/l. Lactate was considered an anaerobic metabolic waste, a paradigm that changed in the first half of the 21st century and is responsible for cellular acidosis. Lactate is a metabolic intermediate that is constantly produced and removed, and its concentration depends on the ratio of the rate of production to the rate of removal, which has been considered as the lactate turnover. It is a precursor of glucose. Lactate is a gluconeogenic substrate, which involves the production of glucose from non-glycosylated molecules, and when formed it alkalinizes the acid-base state (Fernandez et al., 2019).

With training, improvements in sporting performance are sought through different stimuli (the load), the evaluation of the different quantified loads serves to manage the planning in an optimal way the intensity levels. The intensity of training is the most important variable in the prescription of resistance work in which determines the specificity of the stimulus, which must be assessed and distributed over time in a specific way for each athlete (Perez et al., 2019). The manipulation of intensity, its duration and frequency, aims to maximize performance and minimize injuries. In cycling endurance is the main capacity for performance improvement, and predicting the transition of aerobic - anaerobic zones is necessary to be able to determine the different areas of training intensities. To predict training zones the lactate threshold measurement is one of the main methods, and on the other hand with power meters the concept of functional threshold (FTP) is more widely used to determine training zones (Ferney & Leguizamo, 2020). The work planned for the improvement of aerobic and anaerobic areas have objectives, depending on the seasonal phase, of functional improvements that contribute to the improvement of sports performance such as increased capacity to store glycogen at the muscle level, increased muscle capillarization, conversion of fast to intermediate fibers, delaying the onset of lactate. Currently, the advance in technology applied to sports training allows us to access portable hardware with information such as geo position (GPS) and power meters that facilitate access to information from the training session, which the assessment is permanent and in real time, allowing a quantification of the planning and a physiological profile of the athlete, and a work according to the training zones.

Methods

This study consists of performing an incremental progressive load test on 10 amateur volunteer cyclists on an intelligent roller to which each cyclist's bicycle is adapted. The variables are recorded every 4 minutes in steps of 30 W of power, and the % of SmO2 and lactate concentration (mMol/l) are recorded.

Sample

For the present study, the sample as a subset of individuals of the population to be studied was considered. The sample of this study is non-probabilistic according to selection criteria that considered suitable to include for the study those subjects who comply with being trained cyclists, with the practice of cycling for at least 2 years of consecutive training. The cyclists in the sample represent the Elite category within the framework of the classification given by the International Cycling Union (UCI) in terms of being older than 23 years and in activity. The participation of the sample subjects was voluntary, as long as they complied with the established requirements and signed the consent regarding the handling of biological samples.

The N of the initial sample is made of 10 subjects. In the sanitary world frame affected by the Coronavirus, it was requested to lower the n of the sample having been modified to N 6. The 6 subjects of the sample are male, with an average age of 28 ± 5, an average body weight of 66 ± 6 kg, and an average height of 1.70 ± 0.04m.

There is no specific indication to the subjects of the sample regarding the type of intake to be performed prior to the test. Each subject makes the usual intakes to their individual routines. The information of their intakes was collected up to 2 hours before the test in order to have one more input at the time of the conclusions, and it consisted of simple carbohydrates and proteins.

Measuring instruments and techniques

A Tac Flux 2 model smart roller capable of measuring power in watts (w) is used. A portable Humon Hex, near-infrared spectroscopy (NIRS), with two light sources in the window and three photodetectors to measure the intensity of the light that propagates through the skin, is placed on each cyclist's right leg at the level of the external vastus. Via Bluetooth it communicates with a smartphone through the Moxzones app, which displays the % of SmO2 and colored training zones in real time through the data field downloaded to a Garmin device. Training zones are determined by color, green (steady state): when oxygen supply and consumption in the muscle are balanced, the athlete is training at a sustainable pace; orange (approaching limit): when the muscle begins to consume more oxygen than it is being supplied, the athlete is approaching his body's limit; red (limit): when the muscle is consuming significantly more oxygen than is being supplied, the athlete is training at an unsustainable pace; blue (recovery): when the oxygen supply is greater than the consumption in muscle, meaning the athlete's muscles are recovering. Lactate measurement is done through blood samples placed in BM-Lactate reagents at Roche Laboratory's and analyzed with Accutrend Plus, which measures lactate concentration (mMol/l).

A comparative cut-off test was used, and SPSS 1.5 software was used in the statistical analysis. To establish the relationship between SmO2 and lactate concentration, Pearson's linear correlation coefficient was used. The power of lactate threshold and oxygenation threshold was calculated by a double linear regression method. The lactate threshold power was determined for each n of the sample evaluated for the value of 4mMol/l.

Procedure

Prior to the test, each cyclist receives written information about the procedures and aims of the research, together with a declaration of consent in accordance with the principles established in the Declaration of Helsinki, which each cyclist signs autonomously. For this study, an incremental progressive load test with an adapted protocol (Padillla et al. 1991) was performed on volunteer cyclists, who had at least 2 years of consecutive training. Each cyclist using their own bicycle that is adapted to the smart roller. A portable muscular near-infrared spectroscopy (NIRS), the Humon Hex device, is placed on each cyclist's right leg at the level of the vastus externus, and the % of SmO2 is continuously recorded. The device is attached to a strap around the thigh with a Velcro fastener (see Figure 1 and 2), and the muscle oxygen level detectors are attached to the skin. A capillary blood sample is taken by digital puncture and placed on a test strip. The lactate concentration (mMol/l) is measured during the last minute of each 30W step every 4 minutes. The steps are performed until exhaustion, which is indicated by each cyclist when they cannot continue pedaling.

Figure 1. Humon Hex device location

Results

SmO2 and Lactate Trend

The results are presented of the trend behavior of the % of SmO2 and lactate concentration recorded in the power increments carried out on the 6 subjects, represented in a scatter diagram in which it can be seen that as the intensity increases, the availability of muscular oxygen decreases; the muscle desaturates manifesting a decrease in the % of SmO2 (see Figure 2), while the increasing exercise intensity blood lactate increases (see Figure 3). As the intensity (W) of exercise increases, the availability of muscle oxygen needed for oxidative metabolic reactions decreases, oxygen is responsible for oxidizing the available muscle glucose and thus supplying energy to support the demands of exercise. With increasing intensity, the muscles cannot meet the demand for oxygen, so the catabolism of glucose produces lactate and increases its concentration as a product of the lactic anaerobic metabolic pathway for energy.

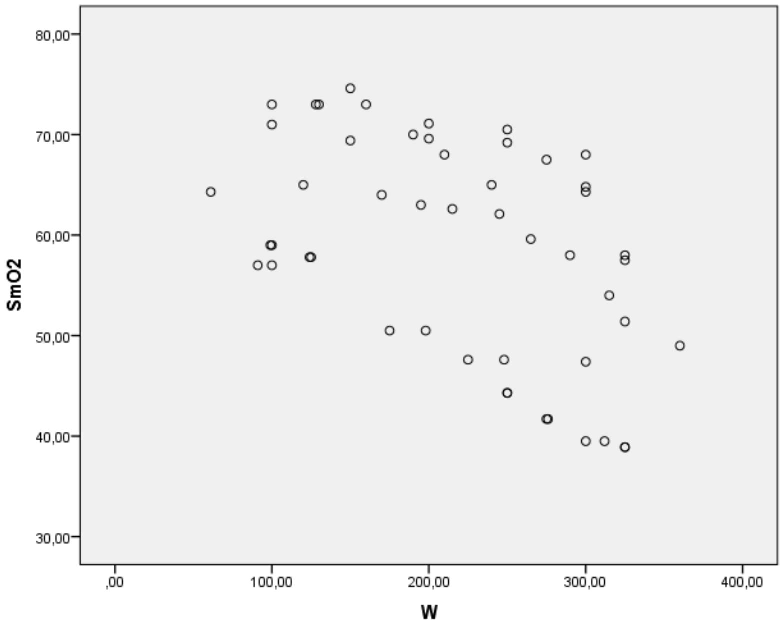

Figure 2. SmO2 and Power Scatter Plot

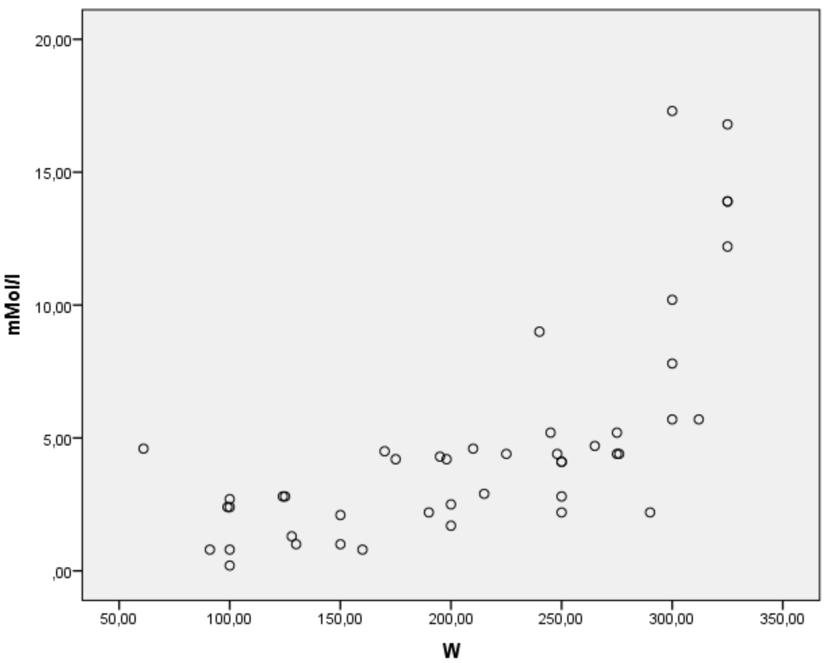

Figure 3. Scatter plot of lactate concentration and power.

Initial averages

At the beginning of the test, prior to the progressive increases in load, the SmO2 and lactate concentration of the subjects were recorded. The average results obtained were 64.3 % ± 9.7 % of SmO2 (see table 1) and lactate concentration of 0.86 ± 0.72 mMol/lt (see table 2).

Table 1
Average % of SmO2 at the beginning of the test

SmO2 resting Mean	N	Standard deviation
64	6	5,3

Table 2
Average lactate concentration at the beginning of the test.

Lactate Mean	N	Standard deviation
1,6	6	1,7

Correlation analysis

Pearson's correlation was calculated for each of the subjects in the sample and the average was - 0.87± 2.7 (see Table 3). From the Pearson's correlation analysis it is obtained as a result that the lactate concentration and SmO2 have a negative relationship, a contradictory correlation between them given that while the value of SmO2 decreases, the value of lactate concentration increases. This negative correlation expresses an inverse behavior between both variables, which means that the availability of muscular oxygen as the intensity increases, it decreases, and the lactate concentration shows the opposite behavior as the power increases, its concentration increases.

Table 3

Pearson's mean correlation between lactate concentration and % of SmO2.

SmO2 Mean	N	Standard deviation
-0,8	6	0,1

Power Lactate and SmO2 Thresholds

For each subject the % SmO2 corresponding to the Lactate Threshold power is determined. The average matched lactate threshold (4 mMoles/lt) was 62 % ± 8.14 % of SmO2 (see Table 4). As for the % of SmO2 data obtained from the NIRS device, the Humon Hex software algorithms, estimated the lactate threshold at an average time difference of 87± 27.5" at an average power of 13± 18.5 W.

Table 4

Average % of SmO2 of lactate threshold.

SmO2 Mean	N	Standard deviation
62	6	8,1

Discussion

SmO2 and lactate behavior

It is found that before starting the test there is lactate concentration in each subject between 0.8 to 2mM/l in the blood, normal concentrations as indicated in studies (Brooks, 2020) agreeing that lactate production occurs at rest, as well as upon exposure to exercise. Banishing the idea that lactate production occurred in anaerobic conditions at the cellular level. The lactate formed even in resting conditions is removed by cardiac and skeletal muscles, but when production exceeds the rate of removal by intense exercise, lactate accumulates and increases its concentration.

As in other studies (Farzam, Starkweather, et al., 2018), with the demand for greater power the oxygen available in the muscle is less, the % of SmO2 decreases and increases in recovery. The progressive loads and the effort of the subjects influence both lactate concentration and % of SmO2, the intensity of exercise influences the ability to produce energy presenting measurable changes at the physiological level; lactate values increase while SmO2 values decrease. Being glycolysis (San-Millán et al., 2020) one of the main energy pathways due to its high rates of ATP generation in anaerobic conditions that satisfies the energy needs, and the release of hydrogen ions begins to overcome its oxidation in the respiratory chain.

Both techniques used are indirect measures of oxidative metabolism, the NIRS device for measuring the % of SmO2 is a technique that ensures accurate quantification of oxygenation changes within the muscle representing the kinetics between supply and demand of oxygen (O2); and blood lactate concentration is sensitive to changes in intensity and duration of the exercise. The measurement of SmO2 behavior is in real time and is recorded while performing the exercise, obtaining blood lactate is invasive and at a certain time when the exercise is paused.

Lactate threshold and power

Blood lactate levels are used to help determine training exercise intensity according to (Fernandez et al., 2019). The lactate threshold allows the identification of training zones to plan loads for performance improvements on an individual basis, understanding that oxidative improvements in glucose are fundamental to avoid lactate increase. During intense exercise, energy is obtained through glycolysis, and the reduction of pyruvate to lactate occurs to sustain the energy demand, but if lactate is not removed, its H+ accumulate and make it impossible to continue exercising.

It is established in each subject the power (W) corresponding to the lactate threshold value of 4mMol/l, which is where the anaerobic aerobic transition occurs as stated and serves as a fundamental data to establish the training zones proposed by (Ferney &Leguizamo, 2020) and make the prescription of the intensity. It was not possible to find a power value (W) of the standard absolute threshold for all the subjects of the sample in agreement with another study (Farzam, Starkweathear, et al., 2018) where there is a difference between the powers corresponding to the 4 mMol/lt of the lactate threshold among the subjects, making it clear as proposed by (San-Millán et al., 2020) the individual metabolic characteristics depending on the amount of lactate produced at a given power. The different potencies in which subjects generate the concentration of 4mMoles corresponding to the lactate Threshold allow to identify those subjects who have better lactate elimination capacity are efficient and therefore export less lactate to the blood (Brooks, 2020).

SmO2 and power Lactate Threshold

In addition to the % of SmO2 values generated by the Humon Hex, it also shows the color graphs, and the interpretation matches according to the rhythm posited by (Farzam, Starkweather, et al., 2018) in the way the muscles are consuming oxygen as the intensity of exercise increases, it is presented orange and transforms to red; the transition from orange to red constitutes the lactate threshold estimate. In the absence of a standard absolute threshold power value (W) for all subjects in the sample, the % of SmO2 per se cannot be considered as a measure of lactate threshold power estimation as there is no % of Smo2 power value to indicate lactate threshold. But making the comparison between the lactate threshold power to each subject, and the kinetics of muscle oxygen saturation with the threshold estimation by the Humon Hex software algorithm gives an average difference of 13W ± 18.5 power and an average time difference of 87"± 27.5, being in another study (Farzam, Starkweather, et al., 2018) the average difference of 21.4W and in less than 3' the lactate measurement. Therefore, it can be considered the result of the analysis of the Humon Hex software as a possible tool to identify training zones for being a non-invasive, reproducible technique, and with results in real time the diffusion of its use is promising in training as in competition.

Conclusions

In this study we see that the intensity zones that can be established from the determination of the lactate threshold, with the records of the % of SmO2, it is also possible to identify the training zones. When correlating a physiological parameter such as lactate concentration with the metabolic zones established from the % of SmO2 through the NIRS technique, it can be observed that in the anaerobic threshold zone there is a correlation where the % of SmO2 decreases due to the O2 demands of the muscles, and the lactate curve that was stable between production and its removal presents a breaking point with increased production of lactate in the blood.

Limitations

As for the limitations, it is observed that SmO2 both at basal level and at the lactate threshold presents a wide dispersion of its values that limits its usefulness. Although the n of the sample is low, the hypothesis can be confirmed, and these data can be considered promising to apply the Humon Hex as an equivalent tool to the lactate test in the indirect determination of the intensity, with the advantage of being non-invasive and efficient in time and cost. As for lines of improvement of theoretical order would be good to have more research in this regard and have a greater n that gives us greater certainty of the data. As for the methodological ones, it would be good to have an impact on the similarity of the intakes prior to the test and to consider anthropometric data, mainly folds and subcutaneous fat in relation to the incidence in the use of the NIRS.

Recommendations

The Humon Hex NIRS device is a tool that, unlike the lactate test, is non-invasive and real-time data can be obtained from the muscle involved in the exercise. It can be used to prescribe training loads, the interpretation of kinetics, and the % of SmO2 changes during exercise can be a very useful reference to determine exhaustion or recovery of the cyclist. The combined use of Humon Hex with the measurement of other parameters such as heart rate, power, or speed, among others, could contribute to the control of training loads and thus understand the physiological repercussions caused by different stimuli. Using this data in the training process together with other variables would be a great advantage that would increase the possibilities of control and enrich the criteria for decision making, which is essential to achieve improvements in sports performance. As for future lines of research, to be able to investigate if the same athletes following a training plan with a view to the improvements of the aerobic capacity, exposed to the same test, it is possible to find greater manifestations of power in the lactate threshold and desaturation zone.

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Receipt date: 06/26/2021
Revision date: 09/20/2021
Acceptance date: 09/28/2021