MUSCLE OXYGEN

Measuring Training Intensity with Muscle Oxygen

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This paper seeks to make the case for Muscle Oxygen as the most precise and universally applicable way to measure training intensity levels available to athletes. By measuring muscle oxygen saturation (SmO2) levels of specific muscles, athletes can accurately monitor training intensity in real time to improve efficiency, reduce injury, and enhance performance.

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WHY IS MEASUREMENT IMPORTANT TO ATHLETIC TRAINING?

Oftentimes, training has a greater effect on athletic performance than any other factor. A properly-executed training regimen can optimize metabolic efficiency and adaptation, improving endurance, technique, and power. A poorly-conceived training program, on the other hand, may cause injury and lead to illness. For these reasons, measurement plays an extremely important role in athletic training.[1]

To maximize efficiency and adaptation, athletes must be able to accurately measure training intensity and duration. This is especially true given that training methods, intensity levels, and durations often differ for each athlete.[1] Such variations in training demand varying levels of measurement. For instance, a longer endurance continuous training workout at steady-state may only require one measurement of duration and intensity, while a high-intensity interval training (HIIT) workout may require numerous measurements of each.

Many athletes incorporate interval and high-intensity training routines into their programs to induce muscle strength adaptations (hypertrophy); however, high-intensity training is also very hard on muscles. Without accurate measurement, athletes tend to over-train during high-intensity intervals, sometimes leading to injury.

Conversely, athletes using interval training sometimes fail to reach higher-intensity levels, slowly wearing down the body without achieving the stress levels needed for adaptation. This is known as falling into a training intensity "black hole."[2]

Regardless of the exercise, accurate measurement is necessary to optimize athletic training efficiency and adaptation, improve endurance and technique, and avoid illness and injury.

PRINICPAL METHODS FOR MEASURING TRAINING INTENSITY

HEART RATE

Perhaps the most widely-used measurement of training intensity, Many athletes, coaches, and sports scientists have settled on heart rate for its universal applicability to all sports, despite limitations of accuracy, science, and localization.

BLOOD LACTATE

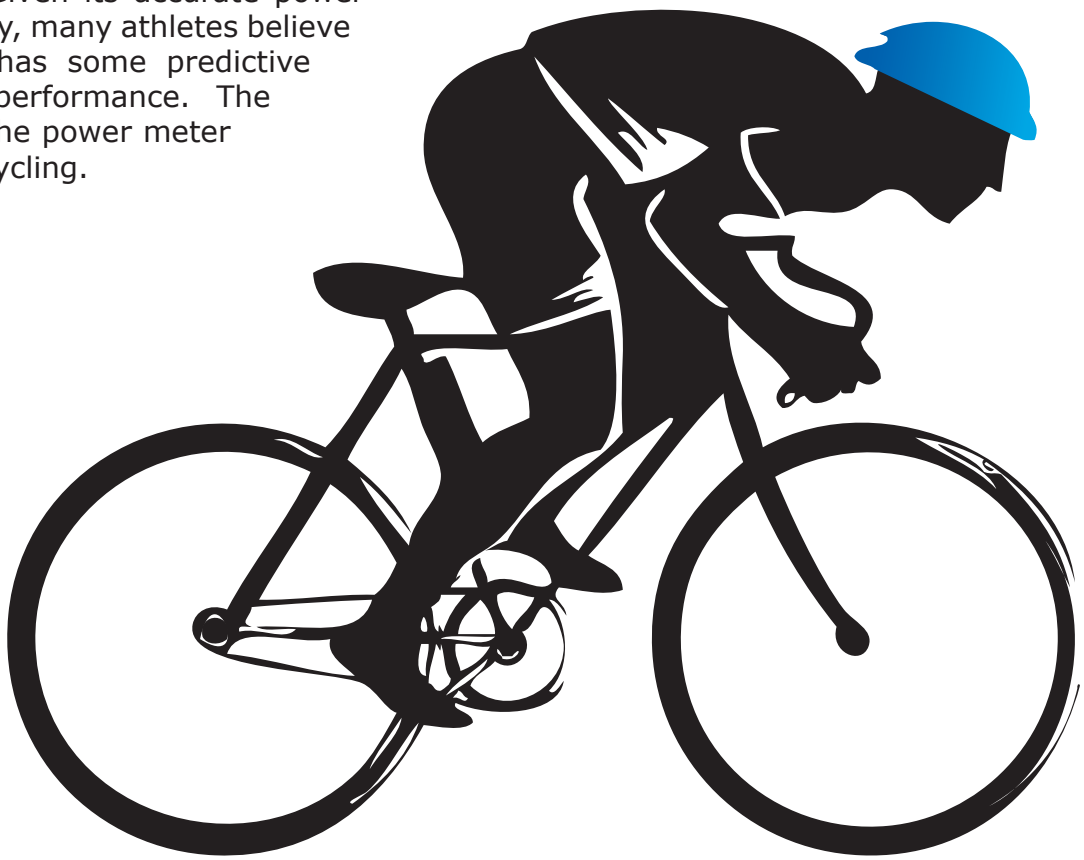
Given the impact of lactate levels on performance, many athletes and trainers measure blood lactate to determine lactate threshold. Blood lactate tests measure the amount of lactate in the blood at increasing levels of exercise intensity. This is usually done with a finger prick. Although blood lactate testing is invasive, it can provide a very accurate picture of the effect of training intensity on lactate.

RESPIRED GASSES (VO2 MAX)

VO2max is the maximum amount of oxygen that can be used for energy in an endurance activity. The higher the VO2 Max the greater an athlete's endurance ability. Because it is a measurement of capacity and not intensity, it has limited use in precision intensity training. Most athletes measure VO2 Max levels by using a metabolic cart while running on a treadmill.

EXTERNAL LOADS (BICYCLE POWER METER)

Power Meters directly measure the propulsion forces on a bike. Given its accurate power-measuring capability, many athletes believe the power meter has some predictive value on racing performance. The main limitation of the power meter is its limitation to cycling.



PRINICPAL METHODS FOR MEASURING TRAINING INTENSITY

CALIMETRY

Measures the amount of heat involved in a chemical reaction. The fitness calorimeter is a tool used to calculate the specific amount of calories consumed. It is sometimes used in weight-loss reduction programs and even athletic training regimens.

EMG (ELECTROMYOGRAPHY)

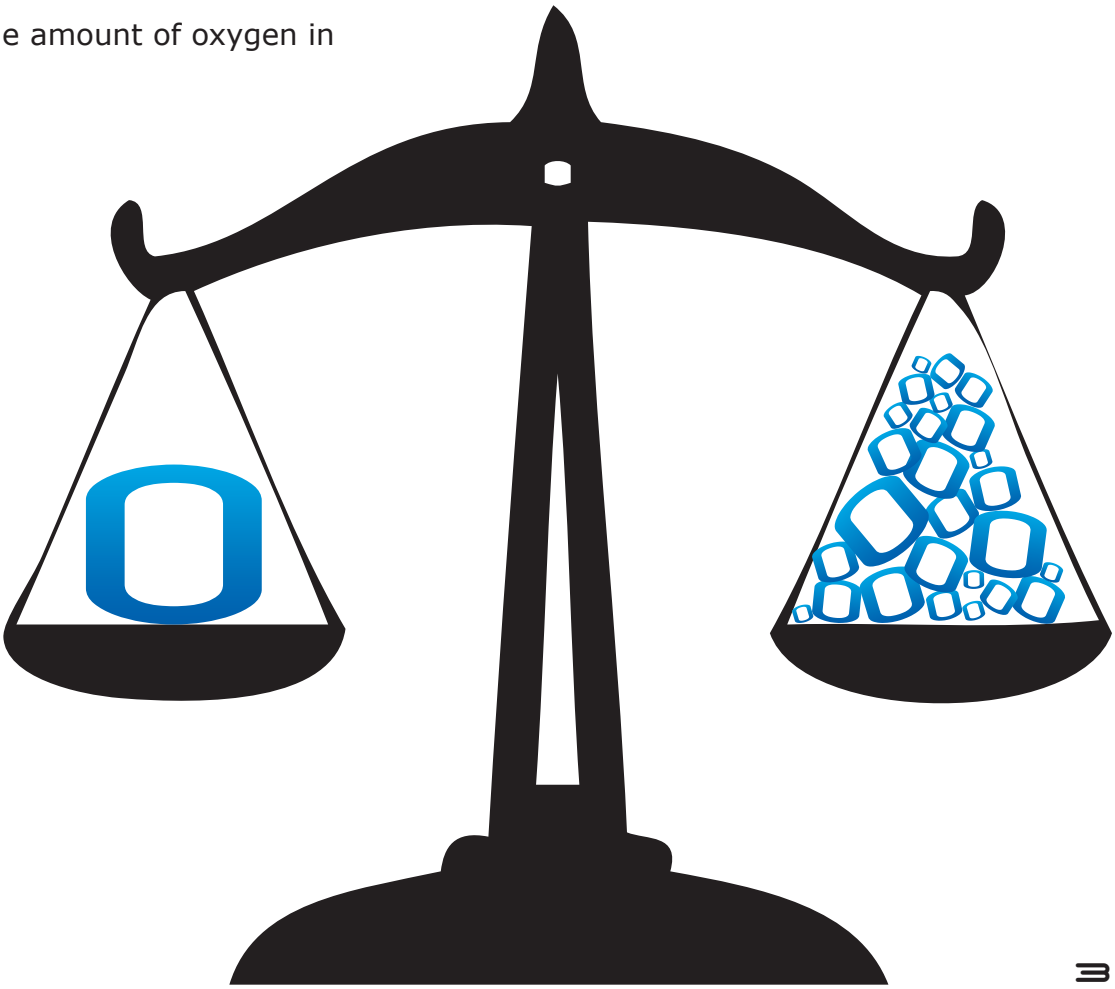
EMG relates to the testing of muscles with tiny electrodes that are inserted into the belly of a muscle. EMG is used to determine which exercises invoke the greatest amount of electrical stimulation within a certain muscle, as higher stimulation levels can lead to increases in muscle size and strength. Surface EMG is an non-invasive, but it doesn't provide accurate values.

VMG (VIBROMYOGRAPHY)

VMG measures the vibration frequency and amplitude created by muscles when they are exerted. In some cases, muscle exertion levels can be inferred from such measurements. Inconsistent results limit the ability of VMG to accurately measure training intensity.

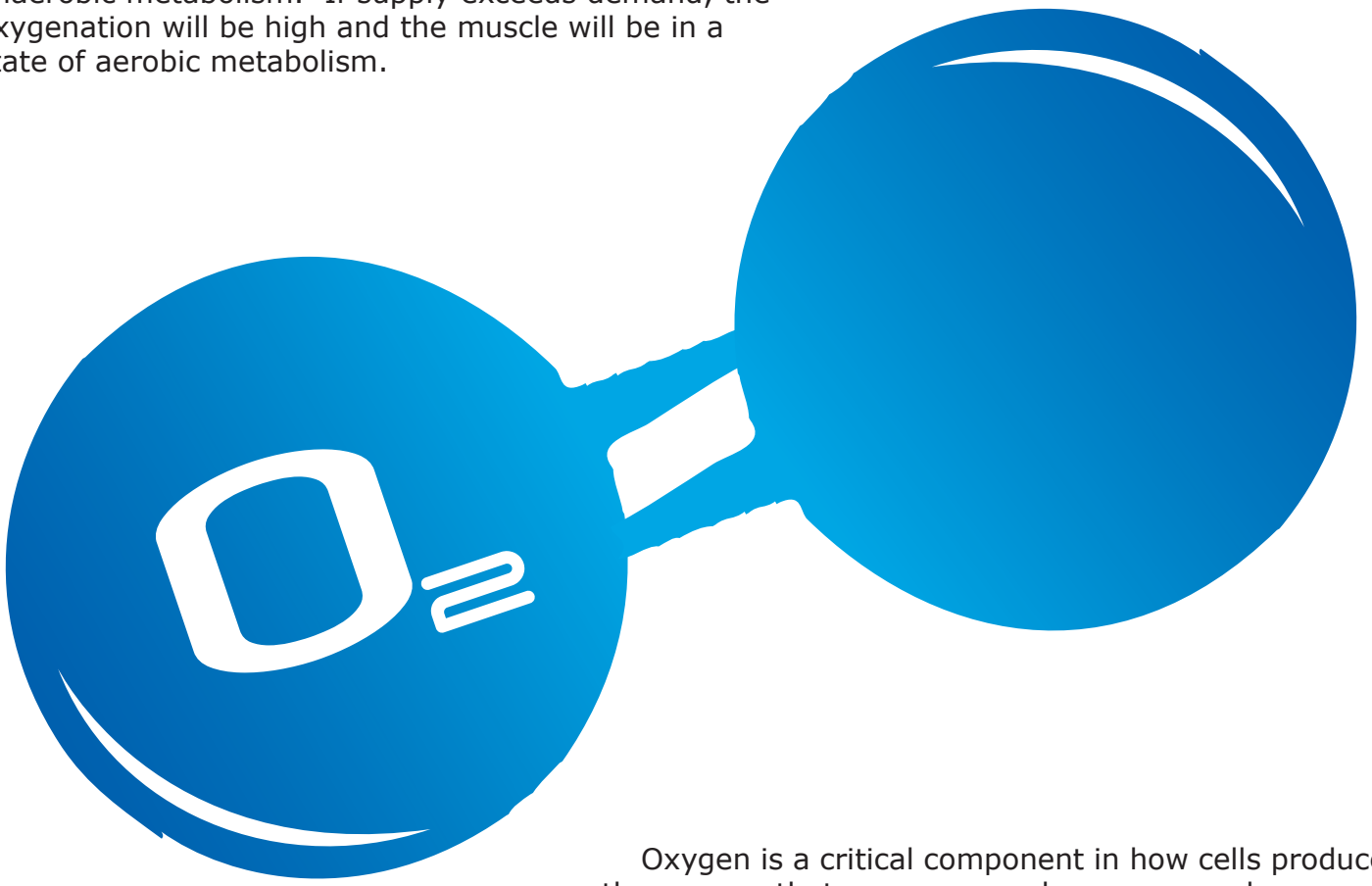
MUSCLE OXYGEN

A direct measure of the amount of oxygen in the muscle tissue.



WHAT IS MUSCLE OXYGEN?

Muscle oxygen is a direct measure of the balance between supply and demand of oxygen in the muscle. If demand exceeds supply, the oxygenation will be low and the muscle will be in a state of anaerobic metabolism. If supply exceeds demand, the oxygenation will be high and the muscle will be in a state of aerobic metabolism.



Oxygen is a critical component in how cells produce the energy that powers muscle, a process known as metabolism. Metabolism can actually occur with (aerobic) and without (anaerobic) oxygen, but oxygen is still important in either case. Aerobic metabolism occurs through the **Krebs Cycle** and does not produce harmful waste products. Anaerobic metabolism occurs through glycolysis and produces waste products such as lactic acid that impair muscle function if concentrations get too high.

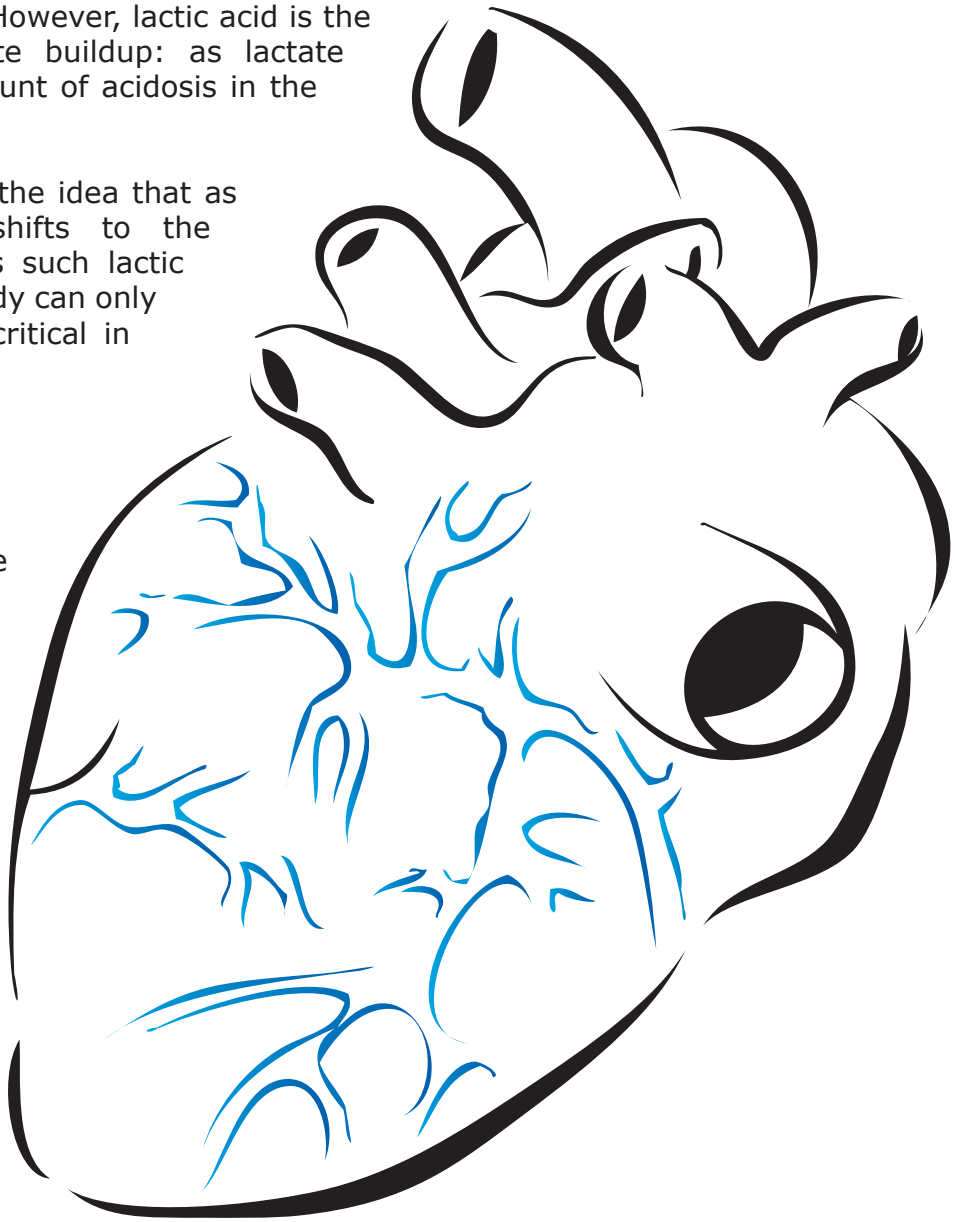
It's important to understand that both forms of metabolism are typically occurring simultaneously; the body does not simply switch from all one state to the other. Rather, the more oxygen present, the more aerobic metabolism will occur in the muscle; conversely, when less oxygen is present, anaerobic metabolism plays a larger role in muscle function.

LACTATE THRESHOLD & OXYGEN DEBT

Many athletes talk about the concept of lactate threshold (also known as anaerobic threshold). Lactate is a byproduct of the body's energy production systems. Lactate is constantly produced, even at rest. However, increases in exercise intensity correspond to an increase in blood lactate levels. Lactate threshold is the point at which the buildup of lactate exceeds the body's ability to clear it from its cells.

The term lactate is often confused with lactic acid. By itself, lactate is harmless, and even beneficial: the heart and other muscles can use lactate as fuel. However, lactic acid is the unpleasant by-product of lactate buildup: as lactate levels increase, so does the amount of acidosis in the system.

The lactate threshold concept is the idea that as the balance of metabolism shifts to the anaerobic, more lactate, and as such lactic acid, will be produced, yet the body can only clear it out so fast. Oxygen is critical in lactic acid clearing process.



Another way of looking at this situation is through the concept of oxygen debt. When a muscle is exerted at intensities where the oxygenation is low and lactic acid is produced faster than it can be cleared, an oxygen debt is built up. As in life, a person can rack up oxygen debt for a while, but eventually the debt is too high and the muscle goes bankrupt - it can't continue to do work.

Debt that is built up must be paid back by flushing the muscle with oxygenated blood. As the body starts to recover from exercise, it uses oxygen to return itself to stasis partly by oxidizing excess lactic acid so that it can be recycled throughout the body.

How is Muscle Oxygen Measured?

Currently, there are three ways to measure muscle oxygen:

Electoro-Chemical

Various invasive methods that measure dissolved oxygen; though there are medical applications, none are currently used in a sports science capacity

Transcutaneous PO2

Measures dissolved oxygen in the skin, it doesn't reach oxygen levels in the muscle tissue. There are many medical applications of transcutaneous PO2, it not used in sports science.

Near-Infrared Spectroscopy (NIRS)

A non-invasive imaging method that uses light in the near-infrared spectrum to measure oxygenated and deoxygenated hemoglobin, the molecule in red blood cells that carries oxygen. NIRS accurately measures oxygen saturation (SmO2) levels in the capillaries of muscle tissue. This is important because unlike the arteries, oxygen is consumed only in the capillaries. NIRS is the principal technology used to measure muscle oxygen in both the medical and sports science fields.

Why Muscle Oxygen is the Best Way to Measure Training Intensity

As mentioned above, to maximize efficiency and adaptation, athletes must be able to accurately measure training intensity and duration. Muscle oxygen provides accurate and continuous measurement of the intensity level and duration of specific muscles, giving athletes and coaches the ability to adjust training in real time to better induce adaptations.

IMPORTANCE OF STRESS & RECOVERY

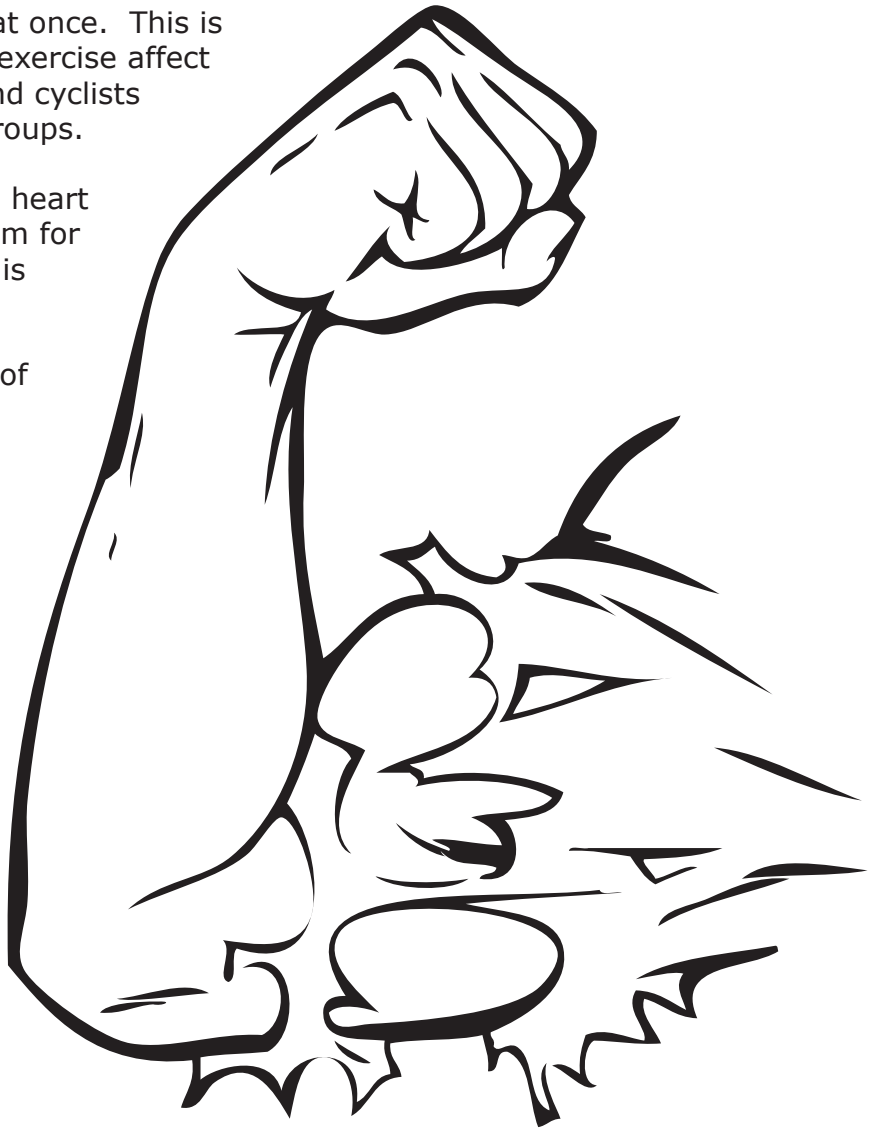
Training is a process of inducing adaptations in the muscle to an increased work load. These adaptations can be in the form of improved muscle and muscle fiber coordination (neurological adaptation) and improved circulation and increased muscle mass (physiological adaptation). Neurological adaptations can occur quickly, over a period of days or weeks. Physiological adaptations take longer.

The process of inducing physiological adaptations involves a repeated sequence of stressing the muscle and then recovering from the stress. This can be thought of as building up a debt, repaying it, and repeating. Muscle oxygenation is the best indicator stress and recovery. It is the accountant for the oxygen debt collection agency. It tells the body when it is accruing oxygen debt, and when and how fast the body is paying it back.

Muscle oxygenation has some significant advantages over other types of intensity monitoring. It allows the athlete to monitor individual muscles rather than the entire body at once. This is important because different types of exercise affect muscles in different ways: runners and cyclists do not use all of the same muscles groups.

Taking heart rate as a sample metric, heart rate stress levels that may be optimum for running may not be for cycling. This is especially apparent for activities like weight lifting, where heart rate may change very little with varying levels of anaerobic exertion.

Recalling that accurate measurement is necessary to optimize athletic training efficiency and adaptation, improve endurance and technique, and avoid illness and injury, muscle oxygen provides athletes and coaches the best method of achieving these ends.



MUSCLE OXYGEN MEASUREMENT DEVICES CURRENTLY AVAILABLE

Though a number of NIRS-based muscle oxygen measurement devices are used for medical purposes, there is currently only one device available in the sports fitness and training space, the Artinis PortaMon.

The Artinis PortaMon is a wireless, portable NIRS system designed specifically for measurements of muscle tissue. The system measures the tissue saturation of the investigated muscle, along with oxygenation changes of oxy-hemoglobin, deoxy-hemoglobin, and total hemoglobin. Aside from its applicability to sports science, the PortaMon is used in rehabilitation medicine, high-altitude research, compartment syndrome, occupational health and peripheral vascular disease.

The PortoMon provides accurate muscle oxygen readings, although its cost (approximately $13,000 USD), along with concerns over durability limit its attractiveness as a field-worn device.

CONCLUSION

Competitive athletes are always looking for ways to make their training more precise in order to improve efficiency and reduce the risk of injury. New technologies are providing athletes more ways to measure training intensity levels with increasing precision. Muscle oxygen is the most physiologically-accurate and universally-applicable method of measuring training intensity levels. Muscle oxygen is universal: it can be used on any muscle, and can apply to any sport or athletic endeavor.

Currently, there is no affordable and accurate muscle oxygen measurement and monitoring device available in the marketplace.

In the end, muscle oxygen is more than a mere training metric: it is the fundamental driver of athletic performance. This is because muscle is what powers the athlete, and oxygen is what powers the muscle.

SOURCES

[1] Sports Science, "Measurement of Training in Competitive Sports"

[2] Sports Science, "Intervals, Thresholds, and Long Slow Distance: the Role of Intensity and Duration in Endurance Training"

MOXY

MUSCLE OXYGEN MONITOR

WHAT IS MOXY MONITOR?

Fortiori Design has developed the Moxy Muscle Oxygen Monitor system to measure the oxygen levels of muscles in athletes while they exercise. Its accurate, real time measurements are fundamental to athletic performance. Oxygen is the fuel that drives the muscles, and muscle oxygen levels are constantly changing with exercise intensity.

Moxy provides the feedback on exercise intensity that athletes are looking for. Our technology is superior to existing measurements because it is completely mobile, continuously recording, and totally non-invasive.

WHY MOXY MONITOR?

Moxy is **Accurate**: Its sensor utilizes cutting-edge medical device technology to produce accurate and consistent readings of SmO2 muscle oxygen levels.

Moxy is **Easy** to Use: Its small sensor and strap can be easily fitted to measure virtually any muscle group.

Moxy is **Durable**: Its waterproof, lightweight industrial design is built to withstand the rigors of elite training.

Moxy is Fully **Mobile**: Sensor data is displayed on a wristwatch, so athletes can monitor their muscle oxygen throughout each workout.

Moxy is **Affordable**: With a price point similar to a GPS heart rate monitor, it is accessible to individual athletes.

CAN I PURCHASE MOXY NOW?

Moxy Monitor will be available for commercial purchase in the summer of 2013. Currently, the 2nd generation prototype of the device is being tested by the Moxy development team, comprised of an elite group of professional trainers, amateur athletes, academics, and doctors who are helping us determine the best ways to use Moxy in various training environments.