Using Moxy for Multimodal Fitness

MOXY

MUSCLE OXYGEN MONITOR

Using Moxy for Multimodal Fitness

Introduction

This eBook should be considered a starting point rather than an ending point for how to use the Moxy Muscle Oxygen Monitor to train multimodal fitness. While sufficient understanding for the utility of monitoring muscle oxygenation exists, we are just beginning to understand how vast the applications of the technology are and how it can be used to optimize training. The goal of the eBook is to provide the reader with some concepts and ideas to develop their own fitness training methods. The examples are meant to introduce possibilities rather than define a rigid program. Ongoing discussion is welcomed on the Moxy Forum at http://forum.moxymonitor.com/. If you are interested in learning more about the specific application of muscle oxygen monitoring in multimodal fitness, please see the curated muscle oxygenation monitoring course housed within the Training Think Tank Classroom.

What is muscle oxygenation?

Muscle oxygenation is a measurement of how much hemoglobin is carrying oxygen in the capillaries of the muscle and the subsequent transfer of oxygen to myoglobin, the oxygen carrying molecule located within the muscle. Muscle oxygenation is a localized measure that depends on level of blood flow, and changes in the hemoglobin dissociation curve. Muscle oxygenation is measured optically with near-infrared light, so it is completely non-invasive. The differing absorption spectra of the infrared light passing through the muscular tissue can be used to identify the relative amount of hemoglobin and myoglobin bound oxygen compared to the amount that is not. It is expressed as a percentage from 0 to 100 and is abbreviated SmO_2.

What can SmO_2 tell us about the physiology of exercise?

Oxygen Consumption. Oxygen transportation and utilization plays a critical role in the exercise capacity of an athlete. Traditionally, athletic assessment, has revolved around the notion that global oxygen consumption (VO_2) is a determinant of oxygen transportation and utilization. VO_2, is a measure of the volume of oxygen that is used by the body when we convert food to energy. VO_2 can be calculated using the Fick equation, which states that VO_2 is a product of cardiac output and the arteriovenous oxygen difference.

$$\text{Oxygen Consumption} = \text{Cardiac Output} \times (a\text{-}v)_{O2Diff}.$$

In the Fick equation, the arteriovenous difference is calculated as the difference in oxygen content from arterial to venous blood, so it is rarely directly measured due to the invasive nature of the measurement; instead, arteriovenous difference can be estimated using the change in oxygen content of inhaled air in relation to exhaled air. However, this measurement is cumbersome and expensive, requiring the athlete to wear a mask or mouthpiece, attached to a metabolic cart which analyzes oxygen and carbon dioxide emissions. MOXY can provide a more practical, direct, and non-invasive measure of oxygen utilization in real-time. Simply by monitoring changes in light absorption MOXY is able to provide a non-invasive means of measuring oxygen utilization dynamically in the working muscle. Furthermore, MOXY's ability to provide oxygen utilization in real-time allows for adaptations in muscle oxygen dynamics as a result of training to be monitored; as such, improvements or setbacks can also be monitored.

Phosphocreatine Recovery. During quick, short bursts, of high intensity or high load movement such as strength training the muscle is reliant on the creation of energy molecules, ATP, from phosphocreatine (PCr), to maintain cellular energy balance. It is now known that the replenishment of this energy system is based primarily on energy synthesis from aerobic (O_2 consuming) means. Muscle oxygenation responds almost instantaneously with the onset of exercise, indicating that high intensity strength training is intimately tied to oxygen availability to the muscle, specifically this could represent the almost instantaneous start of replenishment of ATP via aerobic means. Therefore, monitoring oxygen consumption can be a very useful tool to aid in strength training. It should be noted that the human body can be energetically limited in the ability to combust ATP-PCR for a 1-rep max, which is independent of the Moxy-SmO2 measure that looks at replenishment. Therefore, Muscle Oxygen Consumption measures may be limited for a 1-rep max, but become exponentially more useful as the rep count, and reliance on O_2 consumption, goes up.

How can we use MOXY to guide future training?

The nature of multimodal fitness requires athletes to be strong, have high sport specific endurance capabilities, as well as the capacity to perform repeated efforts without a loss in power output. Muscle oxygenation dynamics reflect changes in muscular metabolism and can be used to guide strength, endurance, and mixed exercise sessions. The utility of MOXY during training is to help the user achieve and maintain a training intensity that reflects the desired profile of improvement. Muscle oxygen saturation (SmO_2) reflects the balance between oxygen delivery and utilization. It is used to monitor, in real-time, non-invasive direct bio-feedback trends between oxygenation and deoxygenation, which coaches and athletes can use for identifying unilateral gait differences, threshold breakpoints which can be used to determine training intensities, load, recovery, and duration of workouts. It can be employed during strength training, interval training, or other forms of high-intensity training. However, with these examples the focus shifts from intensity control to recovery control. In other words, MOXY uses SmO_2 as an indicator of recovery - to identify when the desired level of recovery has been reached, and when the next set should begin.

Benefits of MOXY

While there are many different devices available for performance diagnostic and training guidance, MOXY offers a host of benefits that other devices simply cannot. MOXY is compact, wireless, and non-invasive - all vital properties for physiological application in the field. This differs from many devices that are immobile, wired, or invasive in nature. With SmO_2, MOXY provides a critical physiological measurement that gives the athlete a real-time view of muscle oxygen utilization and delivery in the active muscle areas. In contrast, other physiological metrics such as blood lactate are invasive, have extended lag times and are systemic in nature rather than muscle specific. Lastly, in comparison to other high-tech physiological tools for athletes, MOXY is very affordable.

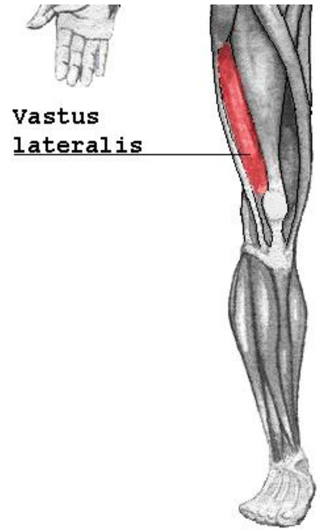
MOXY Assessment Protocols

Equipment Needed

The following assessments require a MOXY Muscle Oxygen Monitor, a device that measures speed/power, and depending on the assessment, a barbell. For all of these assessments, a heart rate monitor is useful as it can help to give insights to how an athlete's cardiac system is managing the workload but not necessary.

Sensor Attachment

For most assessments, the MOXY Sensor should be attached to the prime mover of which ever exercise is most prevalent. Typically, the side of the quadriceps (on the muscle belly of the vastus lateralis) halfway between greater trochanter and lateral femoral epicondyle or the muscle belly of the medial grastrocnemius is most appropriate. As with any NIRS device, ambient light intrusion needs to be minimized, so make sure that the Sensor is properly covered by dark material if used in direct sunlight.



Optional Data Collection

More information can be inferred from the MOXY assessment protocols if additional data is recorded. Below is a brief list of three additional data acquisition devices that could augment athlete assessment:

1) Piko 6 Meter: This device measures forced vital capacity (FVC 6) which is the amount of air an athlete can move in 6 seconds as well as FVC 6 : FEV1% which is the percentage of air you can expire in the first second of your FVC 6 which is a measure of lung strength.

2) Pulse Oximeter: Measures peripheral oxygen saturation at the level of the arteries versus the Moxy which measures at the level of the capillaries.

3) Heart rate monitor : Over the course of tests we look to see if heart rate is trending, if it plateaus, and how this relates to the observed THb trends. If THb is increasing, but HR is stabilized we know the increase in cardiac output is coming from increased stroke volume over heart rate, unless we see trends which indicate a Co2 buildup, which in that case the increased THb is due to chemically mediated vasodilation.

Muscle Oxygenation provides insight into the working muscle and the rate of oxygen delivery and utilization; however, the view is limited to the working muscle being measured. However, trends in SmO_2 and tHb can be indicative of global physiologic limitations. In order to gain the most out of the following assessment it is recommended that further physiological measurements (i.e. heart rate or oxygen consumption) are used.

5-1-5 Assessment to Determine Greatest Limiting Physiologic Factor

IMPORTANT: The athlete should begin the test WITHOUT warming up. It is important to capture the warm-up as a part of the test.

This protocol uses SmO_2 to track differences in oxygen delivery and utilization in order to determine changes in energy metabolism. The key difference is that the purpose of this protocol is to identify trends in SmO_2 with increasing exercise intensity. The theory behind this test originates in the established “Fight or Flight” theory of Walter Canon. The commencement of exercise will create an overshoot of the physiological response, which, if the intensity is sustainable, will result in a return to some kind of homeostasis. If exercise intensity is too high, the body will be unable to return to homeostasis and exhaustion will occur. The identification of different levels of homeostasis, along with the eventual inability to return to homeostasis, will help to identify training zones and physiologic limitations.

Assessment Protocol

The 5-1-5 assessment protocol includes a series of steps in a pattern of 5 minutes of activity followed by 1 minute of rest, and so on (see image below). Each load step in the protocol replicates a given speed/power before a new step is started at a greater speed. During this protocol the goal is to have the athlete complete 4-6 load steps. In order to determine their starting wattage its recommended to use the wattage that can be maintained for a 10-minute max calories assault bike. In the example below the average wattage was 425. Place the 425 as the fifth interval then subtract 50w per load step to determine the rest. One major difficulty with this kind of test, given the extended number of steps and long duration per step, is time frame. For this reason, unlike other testing or assessment protocols, it is more important to correctly judge starting speed and adjust speed increases on an individual basis.

In order to do this, an athlete or coach should have an understanding of how the SmO_2 of the individual being tested may react, perhaps gleaning knowledge from prior tests or different protocols. The first load step should begin at an intensity that will show an initial decrease in SmO_2 followed by a gradual increase in SmO_2 during activity. The protocol is completed when a clear and continuous decrease of SmO_2 is measured during exercise. This also means that the athlete does not have to complete both parts of the final binary step if that is not practical.

An example of the changing load steps is provided in table 1, below. This is just a template for a solid starting point, an athlete might elect to start slower, but the speed selected should elicit running, not walking.

Load Step	**Example Pacing: Wattage during 10 minute Max Cal Assault Bike (425w) (allow +/- 10 watts for each load step)**
1	225w
2	275w
3	325w
4	375w
5	425w
6	475w

Table 1: Example of 425w average power output during a 10-minute Max Cal assault bike

Identifying a Limiter

Upon completion of the 5-1-5 Assessment analysis of the SmO_2 and tHb curves can give insights as to which physiologic system is the greatest limiting factor. The three systems that are the major culprits of limitation to an athlete’s performance are the heart, lungs, or muscle. The identification of which system is limiting is challenging and takes some practice but a brief example can be found in the blog post – 51-5 Assessment Identifying a Limiter.

Skeletal Muscle Extraction Limitation

During exercise the skeletal muscle is the primary user of oxygen. Quite simply, if an athlete is limited by the ability of the muscle to extract oxygen, the SmO_2 curve will decrease with increasing intensity but only to a level > 50%. If this limitation is present at high intensities an athlete may benefit from a block of high intensity interval training which will allow the mitochondria to occupy a larger percentage of the skeletal muscle and thus extract more oxygen.

Cardiac Limitation

If an athlete has a cardiac limitation, then the muscles will extract all the oxygen they can get. Resulting in a very low SmO_2 during high intensity exercise. However, this limitation presents itself with a decreasing tHb, meaning that the heart is unable to deliver an adequate volume of blood to the muscle itself. It's also informative to look at a "low-priority" muscle. In running, this might be a muscle in the forearm. It does some work when they run, but it's not the main power producing muscle. The body will restrict blood flow to the low priority muscles first. If we see low SmO_2 and declining tHb in a low priority muscle, that's a strong indication of a cardiac limiter. The body may even restrict blood flow to the working muscles if needed. This shows up as decreasing tHb in the working muscles.

Pulmonary Limitation

Finally, a pulmonary limitation is similar to a cardiac limitation in that SmO_2 declines during high intensity exercise (~ < 30%) but the major difference is that tHb increases during these intervals. The reason that tHb increases is that CO_2, a potent vasodilator, starts to build-up in the area of muscle being monitored. The pulmonary system is not able to get rid of this build-up thus, a large vasodilatory effect is seen as an increase in tHb. If arterial oxygen saturation is being monitored via pulse oximeter a decrease in SaO_2 below 95%, at sea-level, will also be seen.

Warm-Up

Moxy can also be used to create and monitor warm-up status. A good starting point is to use the results of the 5-1-5 assessment to dictate good starting points for a warm-up. During training, SmO_2 can increase, remain flat, indicating homeostasis, or continually decrease, indicating that fatigue is imminent. During a warm-up the goal is to push SmO_2 as high as possible. The SmO2 response of a good warm-up is an initial depression in SmO_2 followed by a slow rise which eventually peaks somewhere between ~70-90%.

Constructing a warm-up

Start your warm-up with 2 stages of sub-maximal work that push SmO_2 as high as possible. The amount of time that each stage takes should be dictated by physiology, or an increasing SmO_2. The next step in the warm-up can either be some high cadence, hard, short 10-30s intervals and/or 2-3 minutes of race pace work, where the goal is to depress SmO_2 and raise heart rate with enough rest to maximize SmO2. After the intervals the athlete should walk/jog slowly until SmO_2 reaches a new maximum. Repeat this until SmO_2 is maximized. Moxy allows for athletes to tailor a personalized warm-up that allows them to show up to the starting line as ready as possible. For more information read Creating a Proper Warm-up and How to Use Moxy to Monitor Warm-up Status.

How to Use Moxy Muscle Oxygen Monitor to Control and Guide Training

Muscle oxygenation responds within seconds of the onset of muscular activity. It is monitored in real time while working a muscle to guide the number of reps in a set and the rest interval between sets. Two SmO_2 baselines are required to guide training. The Recovery Baseline indicates the normal muscle oxygenation of a rested muscle after a short warm-up. The Performance Baseline indicates the lowest oxygenation that a rested athlete is able to achieve during strenuous exercise. These baselines should be established at the start of every workout to ensure accuracy. They may change over time due to incomplete recovery from previous workouts or due to physiologic adaptations.

Recovery Baseline

The Recovery Baseline is the stable SmO_2 value that occurs during the rest period following an easy warm-up. The recovery baseline is determined after a muscle specific warm-up which will usually result in an increased SmO_2 value owing to increased physiological function. A warm-up using a Moxy device has the same goal as other warm-up protocols, and therefore should reflect a similar routine: muscle and joint mobilization, central nervous system and physiological preparation, and psychological forethought. Moreover, such a warm-up should be specific to the activity or exercise about to be accomplished, use a range of motion that reflects the intended activity, and achieve increasing intensity while avoiding muscular fatigue. Having completed a warm-up, you can now establish your recovery baseline value.

Performance Baseline

The Performance Baseline is the minimum SmO_2 value reached during a strenuous set of a given exercise after warm-up. The determination of this minimum has a subjective component and requires the exertion of maximum effort for the given goal of the exercise. This also means that a second or third set may actually cause the performance baseline to shift as a new minimum SmO_2 value is reached following increased motivation or physiological effort; the means of reaching this new minimum SmO_2 value is then dependent on the specific goal of the training (see Training Recommendations).

Figure 2 shows an example of how to determine Recovery and Performance Baselines for a single arm bicep curl exercise. The light warm-up consisted of 25 reps with a 4-pound weight. The strenuous exercise consisted of 25 reps with a 17-pound weight.

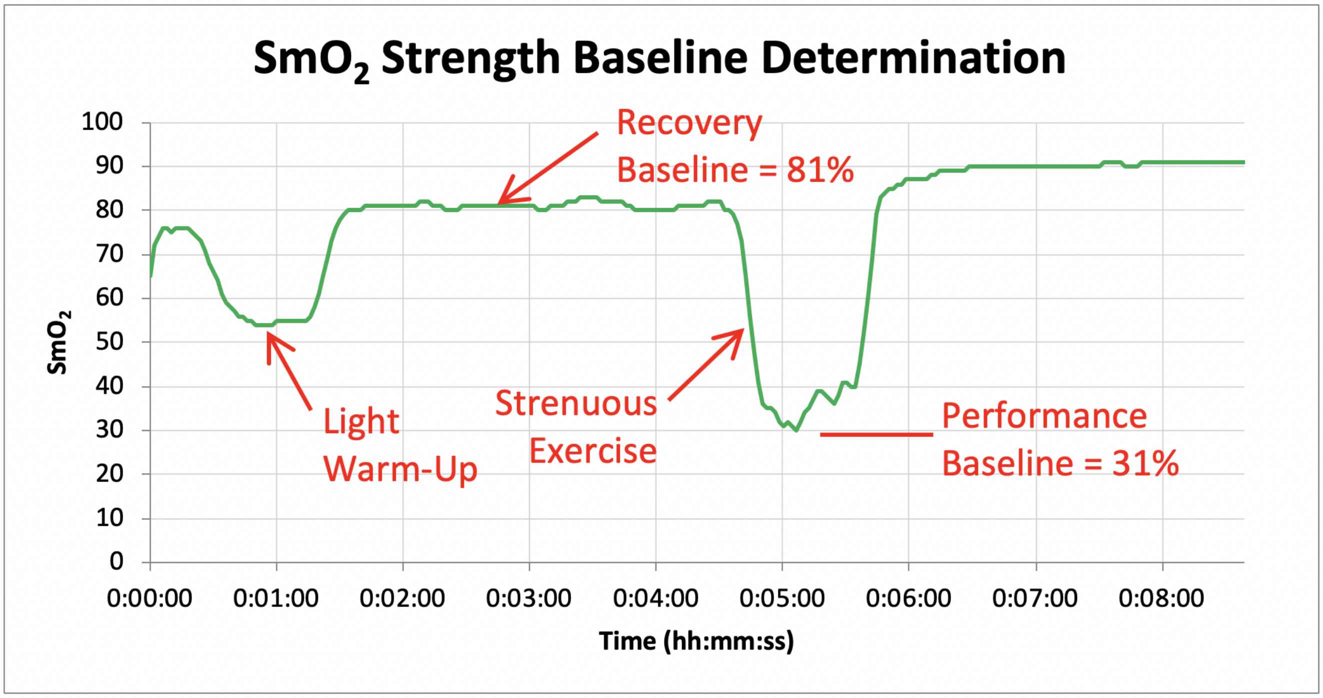


Figure 2 – Determining SmO_2 Baselines for Bicep Curl Exercise

Figure 3 shows data from a strength workout comprised of 15 sets. For each set, the reps are continued until reaching a low plateau. Sets 1-3 show the low plateau reaching the Performance Baseline. Sets 4-7 show that the low plateaus are a bit above the Performance Baseline. Sets 8-11 are after an extended recovery and again show the low plateau reaching the Performance Baseline. The final 4 sets show that the athlete cannot get close to the Performance Baseline, and indeed does not completely recover back to the Recovery Baseline.

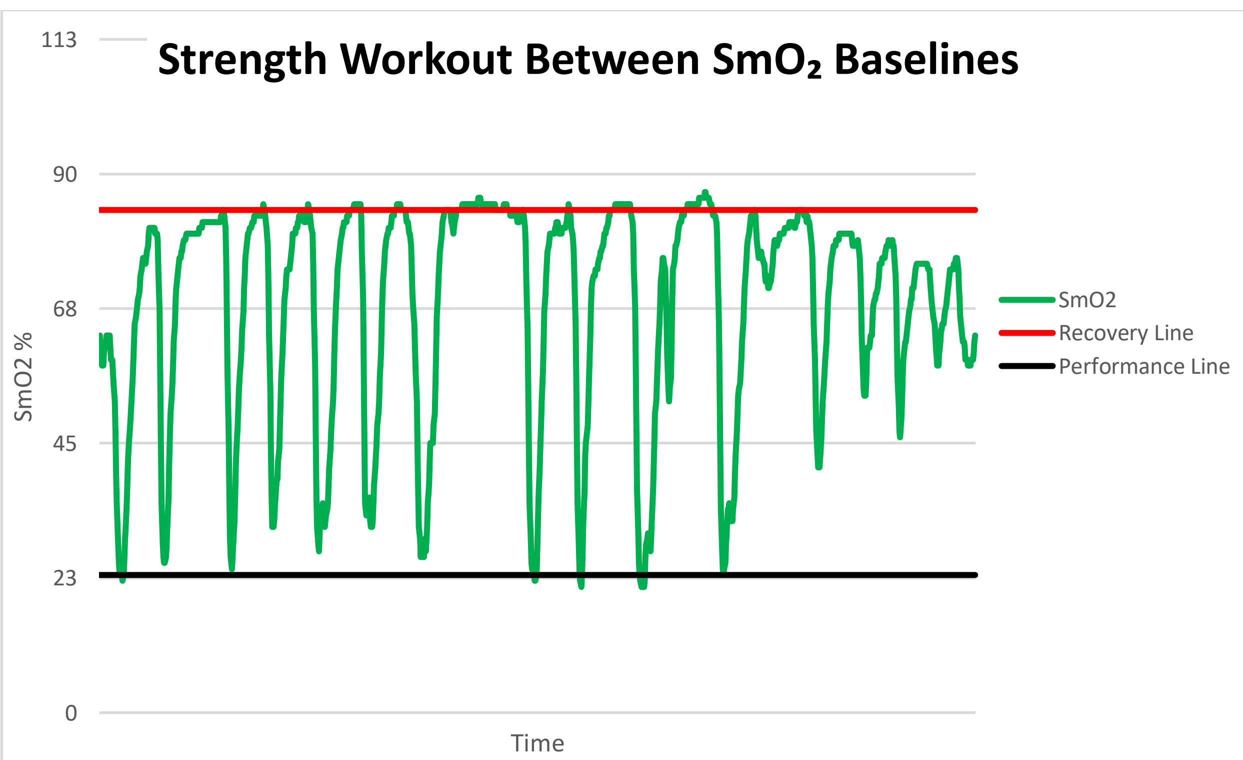


Figure 3 – SmO_2 During 15-Set Strength Workout

Creating Your Own Moxy Workout

Having established your Recovery Baseline following a warm-up, it is now time to start a workout. Before you begin, however, you must decide on the primary goal of your workout. Is it to achieve muscular hypertrophy, maximum strength or power, or muscular endurance? Once you determine this, you are ready to proceed by selecting from the Recovery Protocols and Performance Indicators listed below. The first set (Recovery Protocols) will determine your initial Performance and Recovery Baselines. These two Baselines will guide the remainder of your training as you alternate between SmO_2 recovery and depletion. Once it is clear that either the Recovery and/or Performance Baseline can no longer be reached, your workout is complete.

Recovery Protocols based on SmO_2

Four different Recovery Protocols can be used depending on the desired type of muscular adaptation. This section describes the different Recovery Protocols in greater detail.

- Hypoxic Recovery
- Complete Recovery
- Incomplete Recovery
- Enhanced Recovery

Hypoxic Recovery – No Recovery or Extended Set

The goal of a Hypoxic Recovery is to allow no significant SmO_2 recovery (see Figure 4). In order to achieve this, the set must continue for an extended amount of time with very little rest. This can be accomplished in a variety of ways.

1) A sub-maximal amount of weight can be used for a long series of repetitions until exhaustion.
2) A maximal effort can be immediately followed by a largely reduced weight to extend the amount of achievable repetitions (traditionally called a drop-set).
3) A single rep can be performed for an extended period of time either by creating a very slow motion or with intermittent stops in an isometric contraction.

When this kind of extended set is complete, SmO_2 recovery back to baseline value should be reached. The next set should follow immediately. Depending on the weight and length of time each set is the adaptations seen from hypoxic recovery will either be; 1) endurance, if hypoxia is reached for an extended period of time, i.e. >45s or 2) hypertrophy, if heavier weights are lifted and hypoxia is maintained for shorter periods of time.

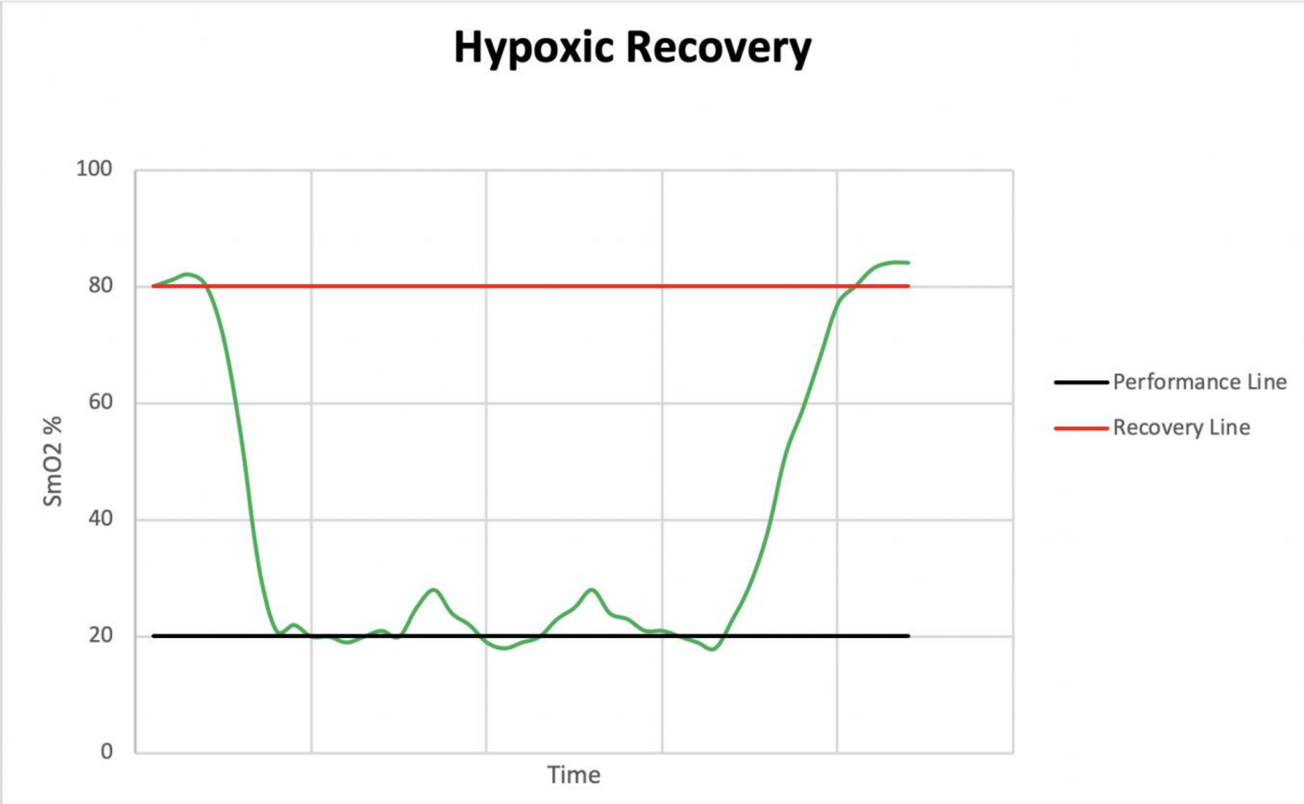


Figure 4 – SmO_2 During Hypoxic Recovery Workout

Complete Recovery

The goal of Complete Recovery is to have SmO_2 return to the stable value, or Recovery Baseline (see Figure 5) before completing another set. The first step in doing so is to establish a Recovery Baseline SmO_2, from which a set is executed until a minimum SmO_2 value, or Performance Baseline, is achieved. The next step is to rest until a stable SmO_2 value, or Recovery Baseline, is reached. As soon as this occurs, the next set is started, and so on. The adaptations seen from complete recovery will range from hypertrophy to maximal strength, depending on the weight used. Lighter weight, but heavier than those used in endurance training, will allow for more hypertrophic adaptations, while heavier weights will lead to adaptations supporting maximal strength.

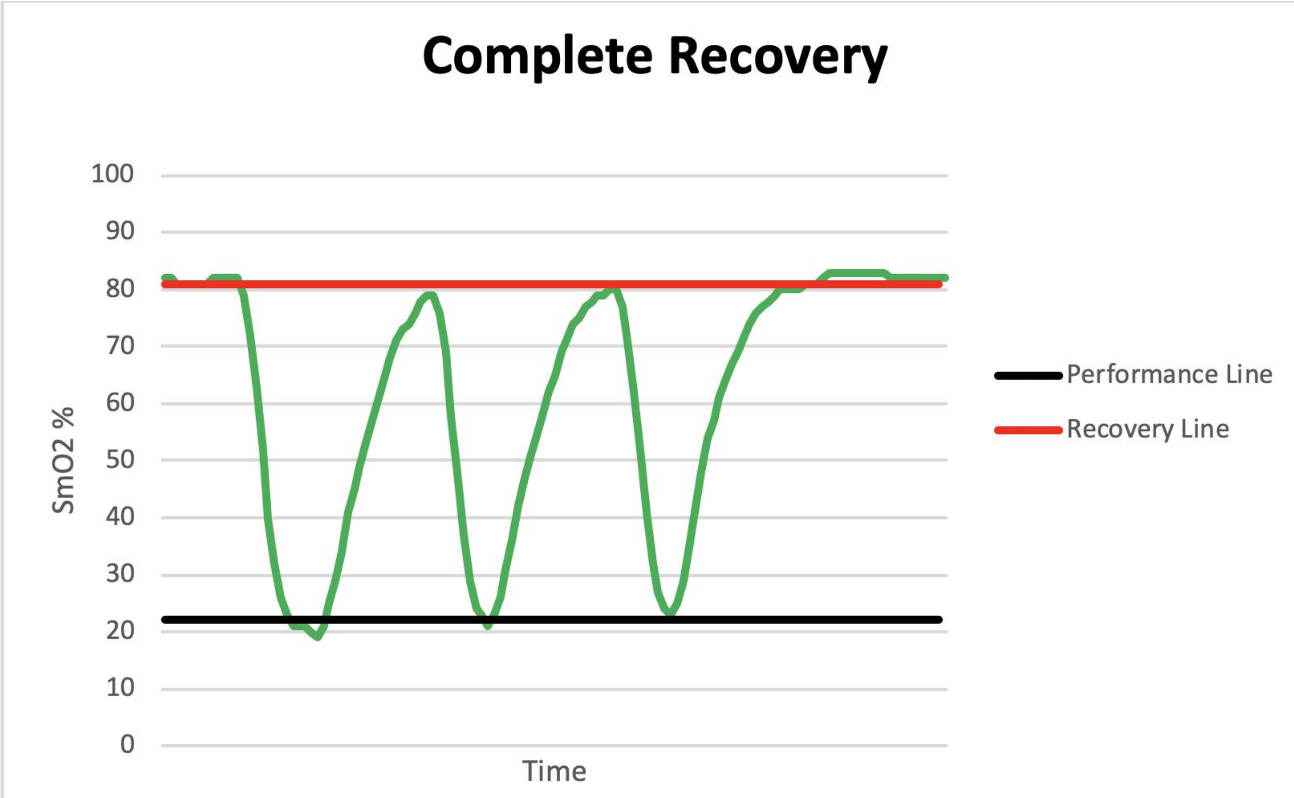


Figure 5 – SmO_2 During Complete Recovery Workout

Incomplete Recovery

An Incomplete Recovery protocol requires SmO_2 recovery to never actually reach the recovery line, differentiating it from a Complete Recovery. Just as in the Complete Recovery protocol, a Recovery Baseline is established after a short warm-up. An initial set is then executed until a minimum value of SmO_2 is reached, establishing a Performance Baseline. After the initial set, the idea is to achieve only limited recovery before starting the next set. The amount of limited recovery prior to starting the next set could be based on numerous factors, such as performance goals or competition types. In the example below (see Figure 6), limited recovery equates to an approximately 50% reduction in SmO_2 level from the Recovery Baseline to the Performance Baseline. When this 50% recovery level is reached, the next set is started. Depending on the weight and length of time each set is the adaptations seen from incomplete recovery could range from endurance (i.e. circuits), to hypertrophy (i.e. drop sets), to maximal strength (i.e. cluster sets).

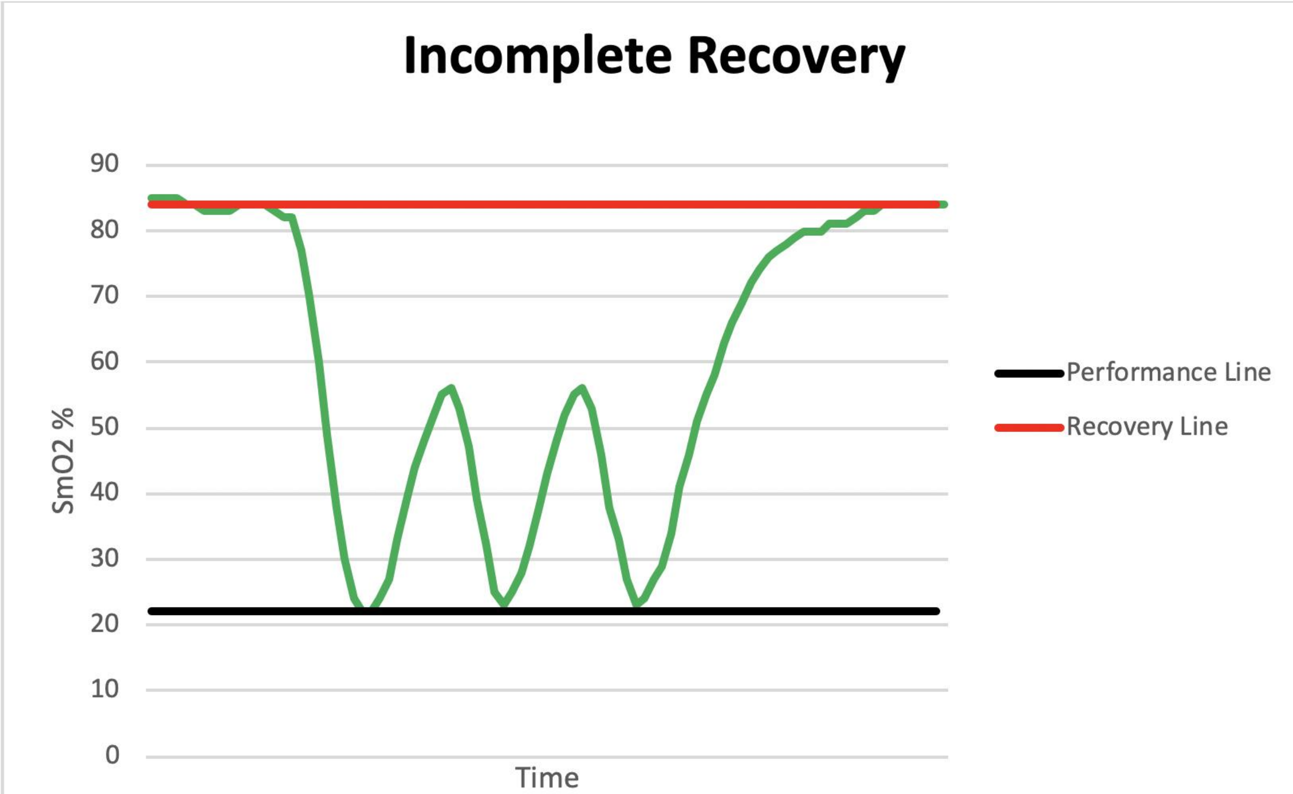


Figure 6 – SmO_2 During Incomplete Recovery Workout

Enhanced Recovery

The goal of Enhanced Recovery is to reach the maximum increase of SmO_2 in-between sets. This value will often exceed the Recovery Baseline due to elevated cardiac output and vasodilation in the working muscle. The following example (see Figure 7) shows the SmO_2 recovery exceeding the Recovery Baseline until it reaches a plateau before the next set is started. The two exercise modalities that should be used for enhanced recovery are maximal strength and maximal power, both require extended rest periods due to the nature (maintenance of proper form) and intention (moving as much weight as possible, and moving weight as fast as possible, respectively) of each.

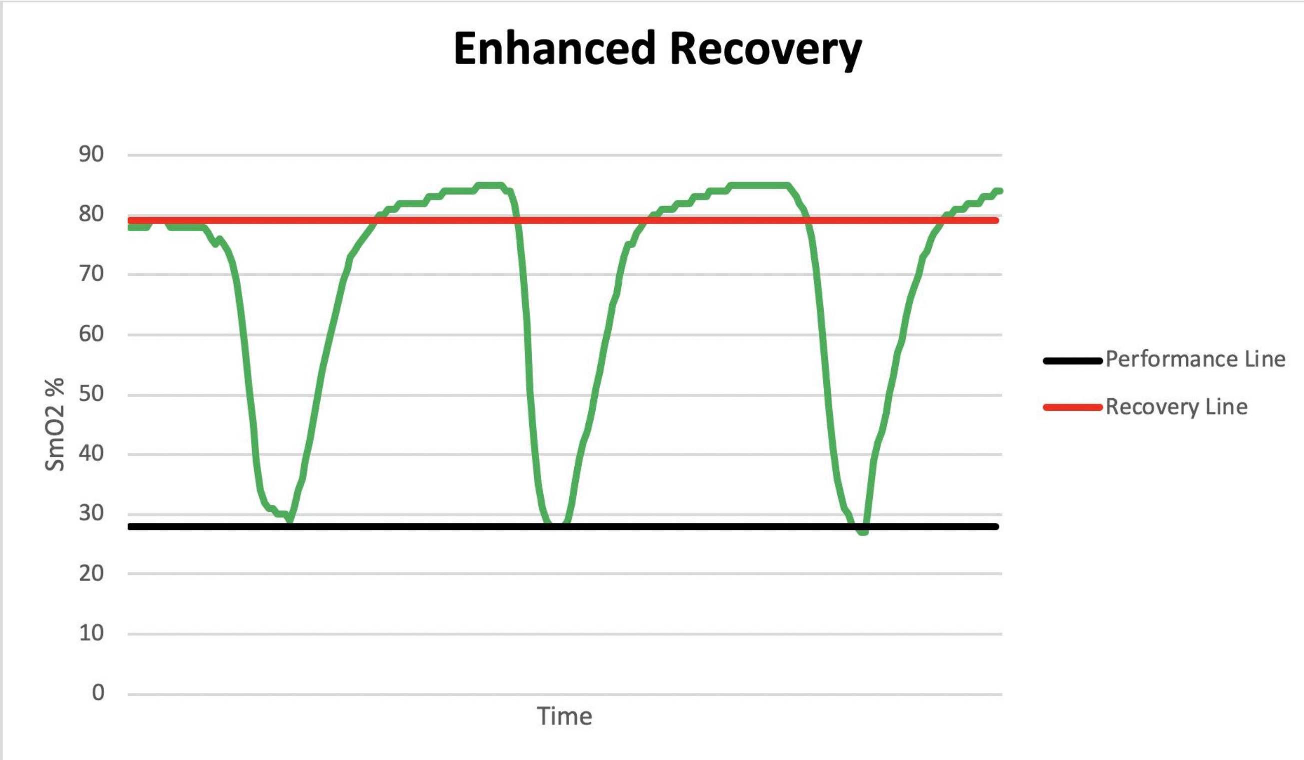


Figure 6 – SmO_2 During Enhanced Recovery Workout

Performance Indicators Based on tHb

Moxy Monitor was developed to measure muscle oxygenation, and therefore the focus of the recovery protocols is muscle oxygenation recovery. However, as a consequence of the muscle oxygenation measurement, a relative value of tHb can also be measured and thereby used to give us a better look at what is happening in the muscle.

tHb is an indirect indication of blood flow in that, an increase in blood flow, in a normal situation, will result in an increase in tHb. The ability and rate of blood flow is determined by how opened or closed the blood vessels are, a phenomenon itself greatly affected by muscular contraction during training. In other words, when we flex our muscles, we impede blood flow; as our blood vessels are compressed, a resulting drop in tHb occurs.

To an extent, this biological process can be used to determine muscular performance. How? As we explained, an increase in muscular contraction is accompanied by a decrease in blood flow, but because venous blood flow (blood flow out of the muscle) has a lower pressure than arterial blood flow (blood flow into the muscle), at a given point we will not see a decrease, but rather an increase, in tHb. This is not because we have normal blood flow. Instead, it is because muscular compression has stopped venous blood flow but is still allowing arterial blood flow, and therefore blood continues to flow in but not out, resulting in an increase in blood volume. This is the first indicator of a given performance rate – a venous occlusion, or a cessation in venous blood flow (see Figure 8).

The second indicator of performance is an unchanged or plateau of tHb. This can occur almost instantly or following a venous occlusion depending on how quickly muscular compression builds up. This plateau of tHb is a result of both venous blood flow and arterial blood flow stopping along with the in-flow or out-flow of blood, which in turn keeps tHb levels flat. This second indicator of performance is known as a complete (venous and arterial) occlusion (see Figure 9). If neither of these two indicators occur, the third one is likely to: a decreasing tHb, usually accompanying a decreasing SmO_2 (see Figure 9). This decreasing tHb means the muscular compression is squeezing the blood vessels together so less blood can flow, but the muscular contraction force is not enough to actually impede blood flow completely. Muscle blood flow becomes effectively impeded at about 50% of maximal contraction force. Please do not confuse this with 1RM, because the progression is different. In order to complete any kind of effective strength training, a minimum contraction force should be achieved. In this case, Moxy can give two indicators of performance using tHb (see Training Recommendations). If neither of these two indicators is reached, workout intensity should be increased.

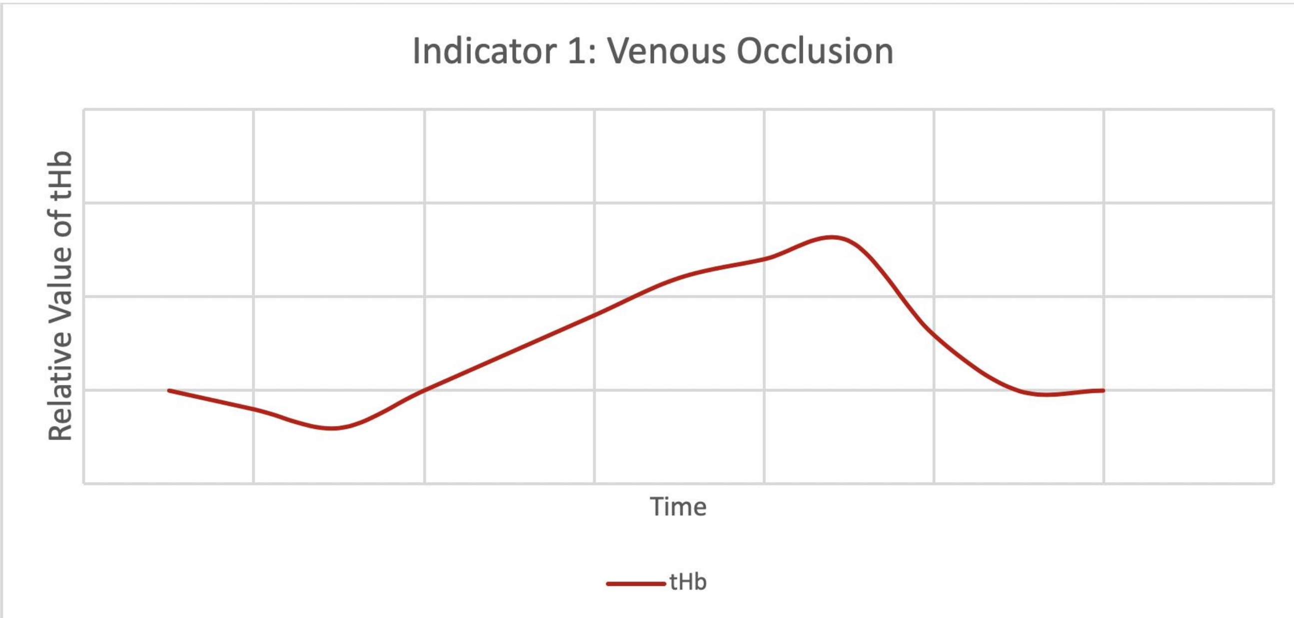


Figure 8 – tHb During a Contraction that Causes Venous Occlusion

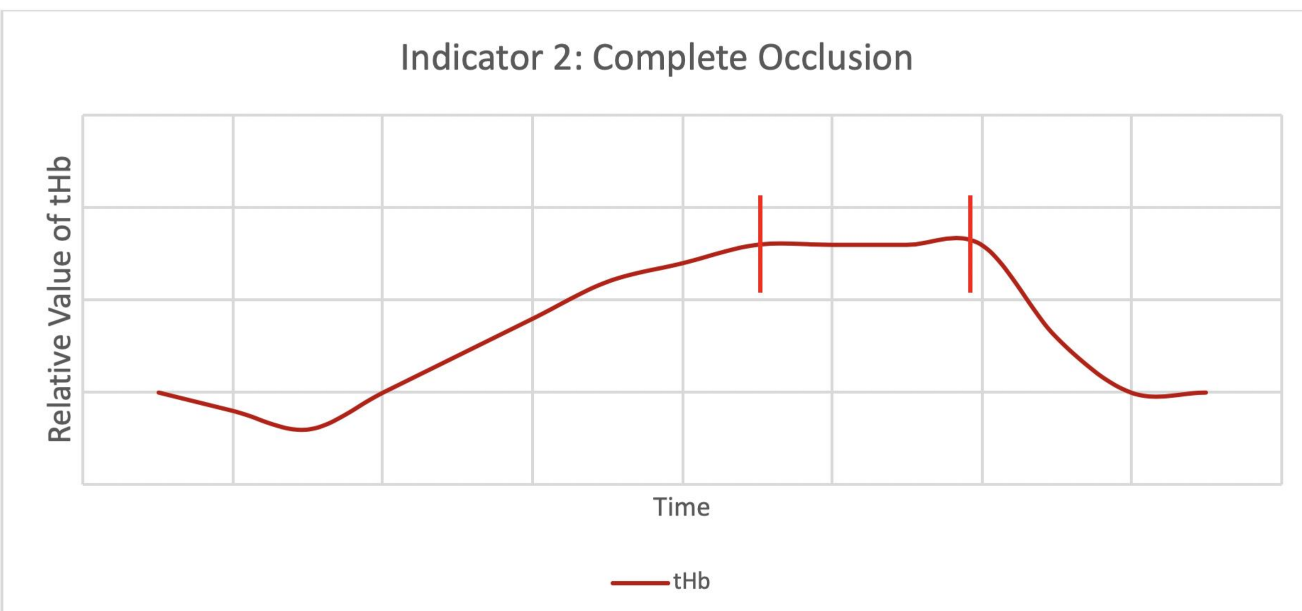


Figure 9 – tHb During a Contraction that Eventually Causes a Complete Occlusion

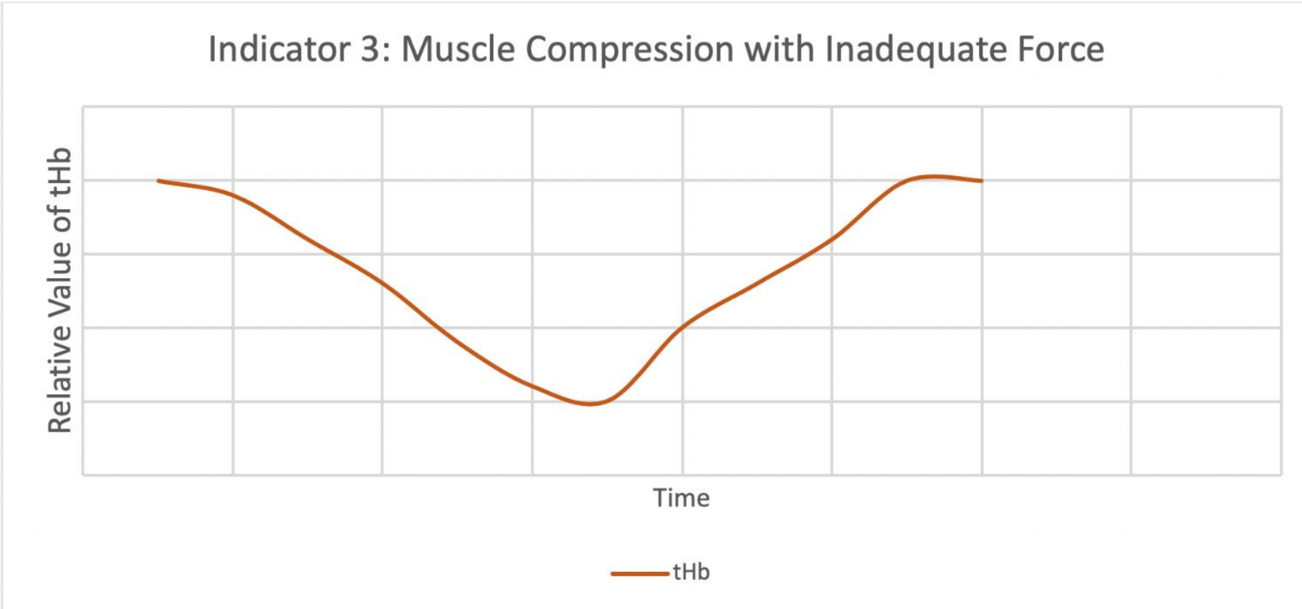


Figure 10 – tHb During a Contraction that Causes a Muscular Compression

Training Recommendations

Using the guidelines established above many different muscular adaptations can be achieved, to get started, examples of multimodal fitness workouts that address each physiological limiter are provided in table 2 below. These are strictly examples and should be changed/customized to the aspects of fitness that you or your athlete need to improve.

Final Comments

One major benefit of using Moxy to monitor training is that it gives the user (athlete and coaches alike) the ability to change and modify training based on oxygen response on a daily basis. The above assessments and determination of training intervals should therefore provide estimations for the intensity of exercise that will elicit the necessary physiologic response. As such, it's important for an athlete to watch their oxygen trends during warm-ups and early intervals of workouts to know if they should increase or decrease intensity to get the necessary stimulus.

Individual physiologic systems have an ability to adapt when the appropriate stimulus is applied. MOXY use permits an effective and ongoing assessment of training stimuli via reflection of adaptation effects. If adaptations are absent, training stimuli require modification regardless of which part of the training cycle or season the athlete is in. MOXY facilitates ongoing assessment and reassessment. It is well known that some athletes adapt to the same training stimulus faster than others; therefore, there may be reason to shift from one area of training to another regardless of temporal location in the cycle, season, or schedule. MOXY provides the data needed to guide these decisions.

This eBook is strictly a primer to the use of Moxy in multimodal fitness, as such if you are interested in a deeper dive into the specifics of using Moxy to help tailor training to each athlete's individual needs please check out the Training Think Tank Classroom.

This course will provide the specifics of using Moxy for dynamic muscle oxygen monitoring during mixed modal training and provide coaches and athletes with an understanding of:

1) What energy systems are and why we should train them
2) Contemporary models of bioenergetics, including the glycogen shunt model
3) Cyclical versus mixed energy system training demands
4) The trainable systems and most common physiological limitations
5) Smo2 trends, tHB trends, and the relationship between them
6) Blood chemistry
7) Utilization, respiratory, and delivery limitations: how to assess for them and train them
8) Case studies for testing and training
9) Sample programs

For some examples of limiter based training workouts:

Limitation	Workout	Termination	Goal
Utilization (muscle oxygen extraction)	(Running time on 45:00 Clock) As many rounds of.... 20 Second Row @85-90% max wattage Rest 1 minute b/w sets	*The test terminates when O2 cannot be depleted to the extent of previous sets, you cannot reach a THb and Smo2 recovery baseline during rest, you can no longer hit the rx'ed wattage, you compensate biomechanically, or effort needed to sustain intensity begins to exponentially increase from set to set. *If this test is done on a Skierg use 90-95% of max watts, and if it's performed on an assault bike use ~75% of an athlete's max wattage.	Repeated maximal desaturation in order to stimulate mitochondrial proliferation (i.e. the ability for the muscle to extract O2)
Respiratory Limited:	(Running time on 45 minute clock) As many rounds of..... AB @70-75% max until O2 drops down to lowest level w/o a plateau Rest until Smo2/ THb baseline	*once you can no longer drop O2 down to lowest level or recover back to baseline the test ends. Note: Can also... -Row @80-90% max watts -Ski @85-95% max watts	Increase breathing rate to strengthen inspiratory and expiratory muscles.
Delivery Limited:	500m Row @increasing pace every 500m (1:55-1:50-1:45-1:40-1:35) Rest 3-4 min x5-7 sets *These paces are for an athlete with a 7:00 2k. The first step should be 10 sec slower per 500m than your 2k pace, then each subsequent step increased by 5 sec/500m every 100m	*If good composure can no longer be maintained.	Drive heart rate as high as possible to increase chances for cardiac driven adaptations.
	2:00 AB building from 70-85% effort (gradually ramping HR across this interval) No rest, into the **following** at 85-90% 'aerobic effort' 20 Wall Ball 20 cal Skierg 200m Run 20 cal Row Rest 4-6 Minutes x4 Sets *Change exercise order each set. Select two upper and lower body dominant movements to force the redirection of blood flow		
	300/250 cal Assault Bike building from a 50-85% over the course of the interval. At around the 10 min mark you should be roughly at a 30 min TT pace, then the last 3-5 minutes should be hard, but tolerable.		

Table 2: Limiter based multimodal workouts