A New Direction For Human Performance

Getting Started With NNOXX

By Evan Peikon

Part I: Introduction to NNOXX

Part I, Introduction To NNOXX, introduces you to the NNOXX wearable, mobile app, and high-performance platform, the three pillars of NNOXX's performance ecosystem. In this section, you'll also learn what muscle oxygenation and nitric oxide are and how to use these breakthrough measurements to unlock your fitness potential.

Part II: Beginner User Guide

Part II, Beginner User Guide, is an in-depth user guide for fitness enthusiasts, weekend warriors, and athletes getting started with NNOXX. In Chapter 2, you'll learn how to make exercise more effective and efficient for general health and fitness, and in Chapter 3, you'll discover how NNOXX can help you optimize your exercise volume, intensity, and recovery for high performance.

Part III: Intermediate User Guide

Part III, Intermediate User Guide, is an in-depth user guide for athletes and serious trainees who want to take their training to the next level. Chapter 4 teaches you how to use real-time biomarker feedback to guide pacing during endurance exercise, and in Chapter 5, you'll learn how to perform physiologically guided training.

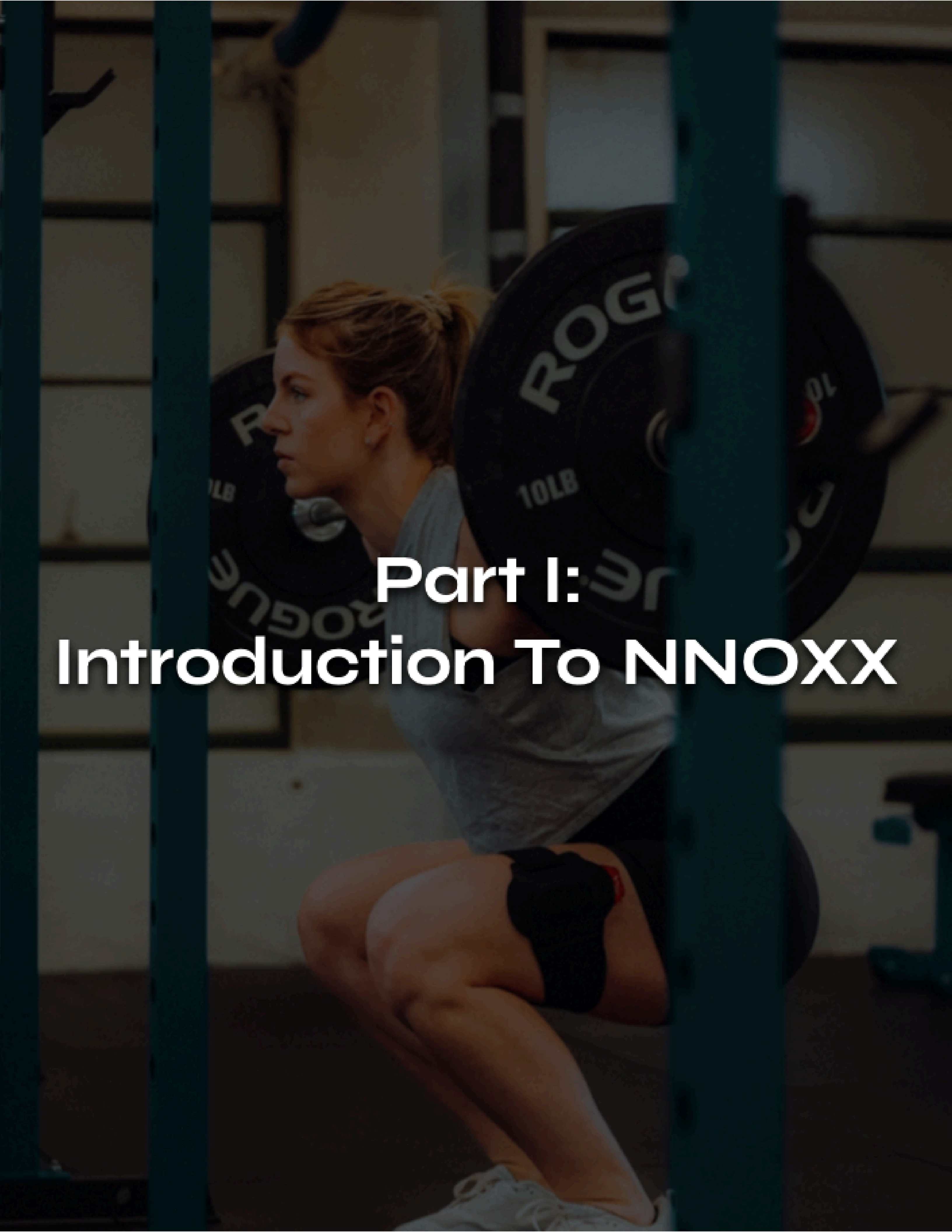
Part IV: Advanced User Guide

Part IV, Advanced User Guide, is an in-depth user guide for elite athletes, coaches, and sports scientists looking to optimize every aspect of their training plan. In this section, you'll learn how to track changes in athlete's fitness and physiology with NNOXX and how to identify physiological limitations.

Chapter V: Expert User Guide

Part V, Exert User Guide, is an in-depth guide to assessing athletes' physiologic responses to exercise geared towards coaches, sports scientists, and exercise physiologists. In this section, you'll learn to identify individual patterns and trends in your biomarker data and how the body copes with the physiological demands of exercise.

Part I: Introduction To NNOXX



Chapter 1: What Is NNOXX?

NNOXX is the first platform that gives the holistic picture inside your working muscles and is the most advanced tool for increasing exercise effectiveness and efficiency. NNOXX achieves this with real-time muscle oxygenation and nitric oxide monitoring.

NNOXX Is More Than Just A Wearable

NNOXX is the first wearable device to measure muscle oxygenation (SmO2), nitric oxide (NO), and movement acceleration non-invasively and in real-time. But, measurements are only as useful as the insights you can glean from them. This is where the NNOXX One and NNOXX One Elite platforms come in. NNOXX One combines the NNOXX wearable with an easy-to-use mobile app, allowing you to track your body's response to exercise in real-time. NNOXX One Elite takes this to the next level by providing you with access to NNOXX's high-performance platform, a web-based analysis platform that allows you to better understand your body's response to exercise and track changes in fitness and physiology over time.

NNOXX's Mobile App – For Any Activity, Anytime

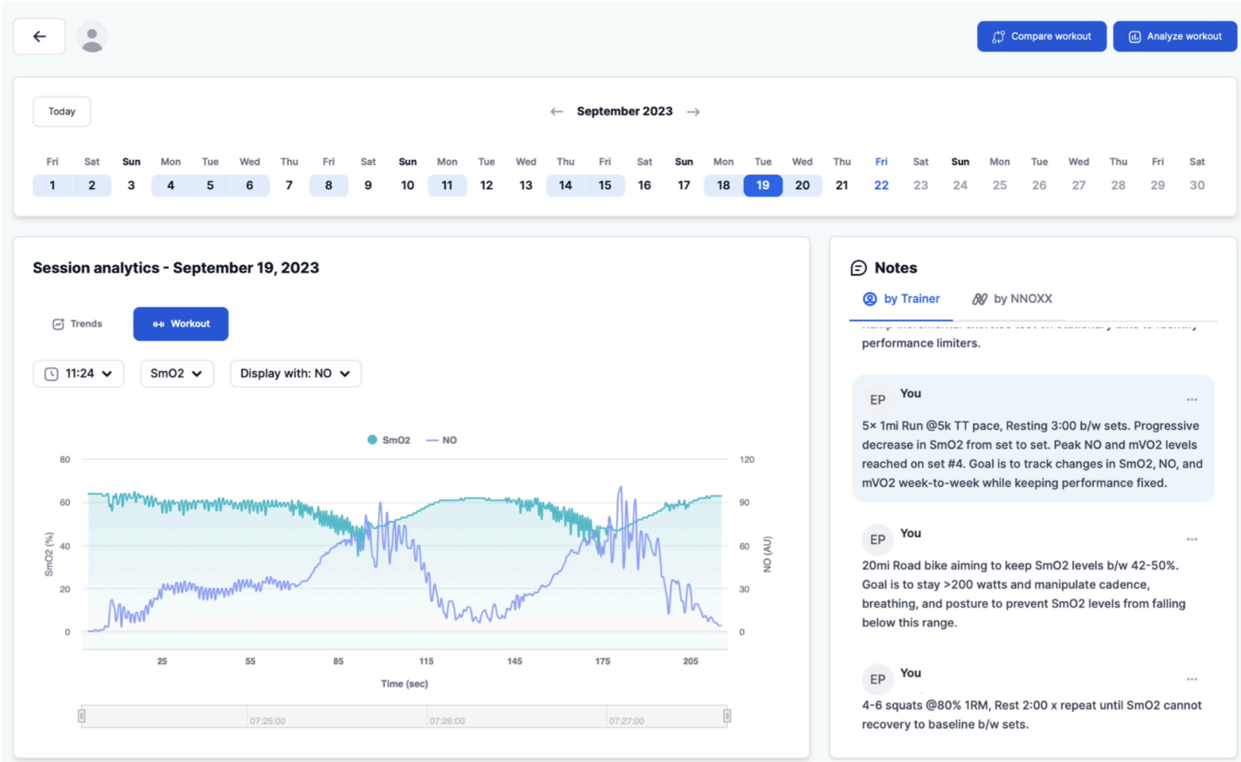
The NNOXX mobile app provides real-time biomarker feedback during exercise, allowing you to adjust intensity, duration, and recovery on the fly for enhanced exercise effectiveness and efficiency

NNOXX's mobile app was designed for everyone, from recreational exercisers to elite athletes. For example, let's say you're a busy parent or professional who wants to get fit but doesn't know how. NNOXX's AI coach feature is just the thing for you. All you need to do is select your favorite form of exercise and how long you wish to work out, and our AI coach will take care of the rest, guiding you through a personalized workout in real time.

On the other end of the spectrum, let's say you're a professional cyclist who struggles with bonking during races. You can use the NNOXX mobile app for real-time pace guidance, helping you adjust your power, cadence, or breathing to minimize fatigue and maximize performance.

For everyone else, you can choose to do your own workout and let NNOXX display your data in real time. After your workout NNOXX will provide you with exercise effectiveness and efficiency scores and personalized workout recommendations.

NNOXX's High Performance Platform Provides Next Level Insights



The NNOXX wearable encapsulates the sophistication of a lab within the compactness of a wearable device. With this innovative tool, users have the freedom to collect data anywhere and during any activity, ensuring that the insights gathered are both accurate and relevant to real-world conditions. In order to facilitate this process, we developed the High Performance Platform.

NNOXX's high-performance platform was designed with elite athletes and their trainers in mind. The high-performance platform is a web-based performance analytics platform available to NNOXX One Elite users. NNOXX's high-performance helps you personalize your training program based on your body's unique needs, track changes in your physiology and fitness over time, and manage training loads to decrease your risk of injury and training.

NNOXX One Elite users can access the High Performance Platform with [this link].

Chapter 2: Understanding Your Biomarker Measurements

Exercise science has traditionally outpaced our understanding of human physiology during exercise, but recent technological advancements are changing that. Our wearable device, NNOXX, revolutionizes strength and endurance training by offering groundbreaking measurements such as nitric oxide levels, muscle oxygenation, oxygen consumption, and acceleration. Unlike traditional methods, these local indicators provide real-time insights into physical exertion levels, responding to changes in exercise conditions. NNOXX bridges the gap between lab-based precision and real-world applicability, allowing users to optimize training regimens efficiently.

Muscle Oxygenation

Your muscle oxygenation (SmO2) level is the percentage of oxygenated blood in your muscles, and it reflects the balance of oxygen supply and demand during exercise. If your SmO2 level increases, your oxygen supply has exceeded your oxygen demand, and vice versa. Alternatively, if SmO2 is unchanging, oxygen supply and demand are in balance.

Tracking muscle oxygenation (SmO2) can help athletes understand how their body responds to different types of exercise and make informed decisions about training intensity and duration, recovery, and other factors impacting performance. Additionally, SmO2 gives a more reliable indicator of physical exertion than heart rate (HR).

In a recent study, titled Near-Infrared Spectroscopy: More Accurate Than Heart Rate for Monitoring Intensity in Running in Hilly Terrain, scientists found that while heart rate was unaffected by continuous changes in terrain and intensity during exercise, muscle oxygenation (SmO_2) reflected these changes and strongly correlated with changes in oxygen consumption. These findings suggest that SmO_2 may offer a more accurate alternative to HR for monitoring exercise intensity, particularly over mixed terrain.

Under normal conditions, SmO2 increases when you transition from exercise to rest. The fitter you are, the higher your SmO2 level will get during recovery, and the faster it will reach its peak value. Average resting SmO2 levels before exercise range from 50-70%, and resting levels following intense exercise can reach as high as 85%.

During high-intensity exercise, SmO2 decreases, indicating that your muscles utilize oxygen faster than it can be supplied, and the harder you exert yourself, the lower your SmO2 level falls. An average SmO2 value after maximal effort exercise is 25-45%; however, it can get as low as 10% in exceptionally fit individuals.

You can gain additional insights from your SmO2 data by cross-referencing it with external load measurements, including acceleration, speed, and power. Fortunately, the NNOXX wearable measures acceleration, which NNOXX One Elite members can view in the High Performance Platform (HPP). Ordinarily, SmO2 and external load are negatively correlated, meaning SmO2 decreases as load increases and vice versa. However, there are circumstances where the above relationships do not hold. The observed data trends in these cases provide important clues about an athlete's internal physiologic state, which you can explore in the preceding data interpretation guide.

Try it yourself
Place your NNOXX device on your bicep and record data using the unguided workout mode in NNOXX's mobile app. You'll notice that at rest, your muscle oxygenation (SmO2) value is stable, which means that your body is supplying adequate oxygen to support the muscle's needs.

Now, flex your bicep muscle for at least ten seconds - you should see your SmO2 value declining, indicating that the muscle is using more oxygen. Finally, relax your biceps muscle. You should see your SmO2 level increasing as you recover.

Good job! You've now demonstrated the three possible muscle oxygenation trends.

Nitric Oxide

Nitric oxide (NO), released from red blood cells, also known as SNO-Hb, is the body's natural regulator for blood flow and oxygen delivery to muscle tissue.

During intense exercise muscle oxygenation (SmO2) levels will decline, since oxygen demand in the muscles exceeds oxygen supply. When oxygen levels in the muscle decrease, nitric oxide (NO) is released from red blood cells passing through the muscle. This signals the small blood vessels to dilate, increasing muscle blood flow and oxygen delivery. When an athlete rests, muscle oxygenation increases and there is no longer a need for increased blood flow. As a result, nitric oxide levels go back down.

This system makes sense when you consider the need to regulate blood flow at the level of individual tissues. When oxygen levels in a tissue are low, nitric oxide is released from the red blood cells, causing the blood vessels to widen, which results in greater blood flow and oxygen delivery. Then when oxygen levels in a tissue are high nitric oxide is not released and blood flow is evenly maintained. Thus, nitric oxide increases and decreases based on a tissue's needs.

Try it yourself
Place your NNOXX device on your outer quadriceps muscle and record data using the unguided workout mode in NNOXX's mobile app. You'll notice that your baseline nitric

oxide (NO) value is low (it may even register as 0).

Begin running, biking, or rowing at a moderate to hard effort - you should see your NO level increasing, indicating an increased need to supply oxygenated blood to the working muscles. Now, rest and relax. Your NO level should decline as your SmO2 value recovers to its resting baseline level.

Good job! You've now demonstrated how nitric oxide levels change based on a tissue's need for oxygen.

Part II: Beginner User Guide

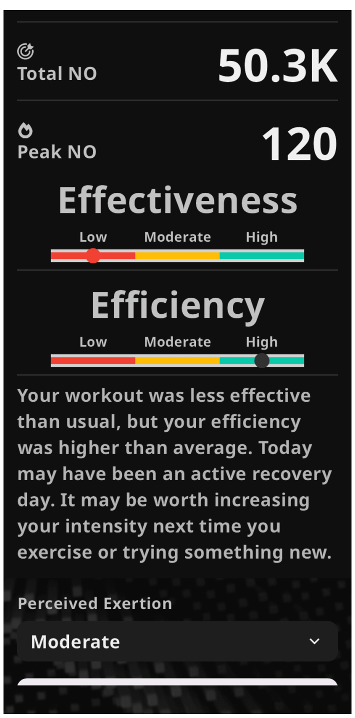
Chapter 3: Optimizing Effectiveness and Efficiency For General Fitness

NNOXX is the first platform that gives the holistic picture inside your working muscles with real-time measurements of exercise effectiveness and efficiency. No more guessing about how long or how much exercise is needed. NNOXX gives clarity into every workout, every time.

To begin optimizing your exercise effectiveness and efficiency all you need to do is select the unguided workout mode in NNOXX's mobile app, then select the type of exercise you're going to partake in and where on the body you're placing the NNOXX device. During endurance exercise, the NNOXX wearable should be worn on the primary locomotor muscle. For activities such as cycling, rowing, or running, the vastus lateralis (outer quadricep) is the most reliable measurement location.

Understanding Your Effectiveness and Efficiency Scores

After completing a workout, you'll now receive an effectiveness and efficiency score, along with a tailored recommendation for your next exercise session. Here's a breakdown of what this feature entails so you can better understand your scores:



Effectiveness Score: This metric gauges the amount of nitric oxide (NO) generated per minute during your workout. The higher your NO production per minute, the greater your effectiveness. Keep in mind that the classification of low, moderate, or high effectiveness is relative to your normal range of values.

Efficiency Score: This measures the amount of NO generated in relation to your movement velocity during exercise. A higher efficiency score indicates that you're producing more NO relative to your speed.

Workout Recommendations: Based on your effectiveness and efficiency scores (classified as low, moderate, or high), the app will provide a personalized workout recommendation. For example, if your effectiveness is high but efficiency is low, it suggests that your workout was more effective than usual but less efficient, which may be unsustainable for you long term. In such cases, the app may recommend reducing intensity in your next session or trying a different type of exercise. Importantly, your effectiveness and efficiency scores are both movement and muscle specific and you'll only get a score after completing three of the same type of workout for a specific muscle within the previous 28 days. This approach ensures accuracy and relevance.

Notably, the effectiveness and efficiency scores, and workout recommendations, are specifically optimized for cyclic activities like running, cycling, rowing, and walking and as a result their accuracy may vary during heavy weight-bearing activities. It's also crucial to understand that effectiveness and efficiency speak to the ability of your workout to generate nitric oxide for improved general fitness and wellness. They do not address sport-specific or performance goals.

Try it yourself
Place your NNOXX device on your outer quadriceps muscle and select your favorite exercise modality, whether that's running, cycling, rowing, or another cyclic exercise.

Now, on separate days, try performing different types of workouts, such as high intensity interval training (HIIT), long slow distance training, active recovery, or your favorite workout.

After three workouts the NNOXX mobile app will provide you with effectiveness and efficiency scores, as well as personalized workout recommendations. Over time you can see how different types of workouts vary in their effectiveness and efficiency.

Chapter 4: Optimizing Exercise Intensity, Volume, and Recovery For High Performance

In the realm of high performance training, optimizing both exercise intensity and recovery is crucial for enhancing performance and minimizing the risk of injury. Monitoring muscle oxygenation levels has emerged as a valuable tool in achieving these goals. By understanding the dynamics of oxygen supply to muscles during physical activity, athletes and fitness enthusiasts can fine-tune their training regimens. NNOXX's muscle oxygenation measurement technology stands out for its high accuracy, providing precise insights into oxygen utilization. This precision enables individuals to tailor their exercise intensity, ensuring an optimal balance between challenging workouts and efficient recovery, ultimately contributing to improved overall performance and well-being.

Optimizing Exercise Intensity and Volume

A common approach to interval workouts involves maintaining a consistent power or speed across all sets. However, a critical flaw lies in assuming that the impact of the same intensity remains constant on muscles throughout the workout. This is where muscle oxygenation (SmO2) comes in.

Imagine running a 400m interval in 90 seconds, dropping your SmO2 level to 40%. After a few sets, you may notice that the same speed only decreases SmO2 to 50%. This change signals dynamic factors at play, such as improved warm-up, increased efficiency, or other adaptive responses. In this scenario, recognizing your body's enhanced preparedness becomes pivotal. To optimize your workout, you may want to increase your intensity to challenge your now-better-prepared muscles. For example, you may increase your speed by running 400m in 84 seconds, resulting in a SmO2 level closer to 40%, thus matching your exertion from the first set.

Conversely, if after a few sets of running 400m in 90 seconds, you find that your SmO2 is dropping far below the initial 40% baseline, it's a clue that your muscles are under excessive stress. The solution is straightforward—reduce speed. This adjustment ensures you don't push your muscles beyond their current capacity, mitigating stress and potential fatigue.

Integrating SmO2 insights into your interval training involves a real-time assessment of muscle response. It empowers you to adapt and tailor each set to your body's evolving readiness, transforming your workout from a fixed routine to a dynamic and responsive experience.

These same concepts outlined above can even be applied to auto-regulating exercise volume based on real-time biomarker feedback. For example, instead of adjusting your power output, speed, or weight from one set to the next, you may choose to maintain your load and observe set-to-set changes in muscle oxygenation. Let's take the sample example from above, where you run 400m in 90 seconds, resting 60 seconds between sets. On the first set, you drop your SmO2 level down to ~40%, which we'll call your 'target intensity'. Now, each time you perform another set, we can compare your finishing SmO2 level to your target intensity on the first set, and if it drops 5-10% lower than the first set, you may choose to end the workout. This approach allows you to auto-regulate your exercise set volume based on your body's response, optimizing your exercise stimulus based on your readiness that day.

Optimizing Recovery Duration

Muscle oxygenation (SmO2) is a powerful tool for tailoring recovery between exercise intervals. The key lies in observing how quickly SmO2 returns to baseline levels after an interval, providing a real-time indicator of muscle readiness. I've found that achieving SmO2 levels above 65% is a reliable signal that my muscles are sufficiently reoxygenated, signaling readiness for the next interval. However, optimal recovery SmO2 level will vary from person to person; as a rule of thumb, your resting SmO2 level after a sufficient warmup is a good target.

The beauty of using SmO2 to guide recovery is its individualized nature. The time required for SmO2 to recover can vary and is influenced by factors such as fitness level, workout intensity, and accumulated fatigue.

As fatigue accumulates throughout a session, the time needed for recovery tends to increase. For example, say I'm performing ½ Mile Echo Bike intervals at 400 watts, resting until my SmO2 reaches my recovery baseline after each set. On the first set, my SmO2 starts at ~65% and gets as low as ~40% by the end of the interval. Then, after my set ends, my SmO2 increases and takes ~75 seconds to recover to 65%. After a few more sets, my SmO2 now takes closer to ~90 seconds to reach ~65%. These real-time measurements of SmO2 allow for dynamic adjustments, ensuring that rest periods are optimized based on the unique demands of each set.

Utilizing SmO2 to optimize rest between intervals is a practical approach backed by scientific understanding. It provides a tangible metric for gauging muscle recovery, helping you avoid underestimating or overestimating your readiness for the next set. This personalized feedback loop ensures that your rest periods align with your body's real-time needs, contributing to improved performance, reduced risk of overtraining, and a more effective and tailored workout experience.

Part II: Intermediate User Guide

Chapter 5: Real-Time Pacing Guidance For Endurance Athletes

Traditionally, systemic physiological responses such as VO2, heart rate, and blood lactate changes have been used to quantify exercise intensity and inform athletes' pacing strategies during training and racing. An alternative approach is to use local indicators of a working muscle's status, such as muscle oxygenation (SmO2) and nitric oxide (NO), which you can measure with your NNOXX wearable device.

Where Do I Put My NNOXX Device?

To guide pacing during endurance exercise, the NNOXX wearable should be worn on the primary locomotor muscle. For activities such as cycling, rowing, or running, the vastus lateralis (outer quadricep) is the most reliable measurement location.

However, it should be understood that there is a heterogeneity of responses across different muscle sites. As a result, if you were to put a NNOXX device on two different muscles you would see two different responses to exercise. This is of little concern for the majority of activities, but becomes increasingly relevant during full-body endurance sports such as Crossfit, where the primary locomotor muscle can change over the course of a workout. Due to the individualized nature of such events, this guide will focus solely on cyclic activities such as cycling and running.

How To Use Your Data To Guide Pacing In Real Time

With trial and error, you can determine your minimum and maximum SmO2 values and how they change based on how well-rested and recovered you are. Additionally, you can learn to identify what ranges of values are easy or challenging to maintain, which can be used as a real-time feedback tool to guide exercise intensity.

Once you understand how varying SmO2 levels relate to your effort, exertion, and fatigue, you can associate different bodily sensations with your SmO2 level. For example, I've found that when my SmO2 level gets below ~55%, my breathing starts to elevate ever so slightly. However, I can still converse and sustain this SmO2 level indefinitely without feeling like I'm exerting myself. Additionally, I commonly perform long-duration (>2 hours) cycling workouts in the 50-60% SmO2 range.

When my SmO2 level is between ~40-50%, my breathing starts to elevate, and I begin to feel a mild burning sensation in my muscles. This level of exertion is comfortably challenging, and I can maintain this SmO2 level for an extended duration. However, once my SmO2 is 30-40%, my breathing becomes labored, and my muscles have an uncomfortable continuous burning sensation. This level of exertion is unsustainable, and I have limited time I can spend in this intensity range before fatigue starts mounting.

Finally, if I push below 30% SmO2, I can no longer coordinate my breathing, and my muscles rapidly fatigue. Often, I'll see my SmO2 level in this range if I'm aggressively climbing a hill on my bike. Knowing that I have limited time I can spend at this oxygenation level, I'll use it as a sign that I need to reduce my power or speed to avoid 'spilling over' to the degree that I cannot recover.

Through trial and error, you can learn to manipulate your muscle oxygenation level during exercise by altering your power, cadence, breathing volume and frequency, and body position. For example, suppose you're cycling and are approaching your minimum SmO2 value. In that case, you can lower your power output to prevent your SmO2 from bottoming out. Alternatively, say you're in a race, and a competitor passes you. You may notice that your SmO2 value is relatively high, meaning you have sufficient energy reserves to increase your power output. In another instance, you may be on a long bike ride as part of your training, holding a submaximal power output and aiming to keep your muscle oxygenation level in a moderate intensity range. In this case, you could adjust your gears and cycling cadence to see if you could increase your SmO2 without changing your power. If so, you've improved your movement efficiency.

You can even work on manipulating your movement cadence, breathing volume and frequency, and body posture to increase your pace at a given SmO2 level. For example, I'm running one-mile repeats with my SmO2 at 35-45%. From set to set, I could try running with a different cadence, increasing my breathing frequency while maintaining my volume, or altering the position of my torso to see if I can increase my speed without my SmO2 level going below my target range.

Try it yourself!

Place your NNOXX device on your outer quadriceps muscle and record data using the unguided workout mode in NNOXX's mobile app. Now, begin running, biking, or rowing at a low intensity, observing your muscle oxygenation (SmO2) values.

After a few minutes, increase your intensity to a moderate exertion level, and observe how your SmO2 value changes. Once your SmO2 has stabilized, you can try exercising at a hard exertion level or even try to do a 20-30 second sprint. How low did your SmO2 level get? After you've rested and recovered, how high did it get back up to?

With experience, NNOXX users can learn what SmO2 values correspond to their easy, moderate, hard, and maximal effort intensity zones. Additionally, advanced users can experiment to learn how their cadence, breathing, and body position impact their muscle oxygenation readings. Below is a sample workout for cyclists:

10:00 Wattbike at 90-100% FTP, Rest to recovery x2-4 Sets

Start with what feels like normal relaxed breathing for this effort. If you feel like you're not getting enough air in, aim to increase your respiratory rate (RR) while maintaining the depth of your inhale and exhale. Try shifting your gears and cadence as you get comfortable with this power output. Can you increase your muscle oxygenation while keeping your power stable? If so, does it feel easier to sustain this intensity? Now, try altering your position on the bike - how does this impact your SmO2?

Whether or not you're a competitive athlete, you should try this type of to experience how your cadence, breathing, and body position can impact your muscle oxygenation values, even at a fixed power output or speed.

Chapter 6: Physiologically Guided Training For High Performance Athletes

How hard should you push yourself during training? How many intervals should you do, and how long should each be? Is active or passive recovery better for you? Until now, there haven't been easy answers to these questions. But, with NNOXX, you can get real-time feedback during exercise, allowing you to fine-tune your training.

The idea behind physiologically guided training is to do your own workout with your goals and training plan in mind. At the same time, NNOXX's mobile app displays your data in real-time, helping you auto-regulate your exercise intensity, volume, or recovery.

Select the unguided workout mode in your NNOXX mobile app to perform physiologically guided training, then attach your NNOXX wearable to the primary locomotor muscle for your chosen activity. Once you've selected your exercise modality and sensor placement, performing physiologically guided training can be as simple as exercising within your desired muscle oxygenation training zone, as explained in the previous section. However, more advanced users may wish to use their muscle oxygenation (SmO2) and nitric oxide (NO) levels and trends to perform physiologically guided training designed to target specific training adaptations, as explained in the following sections.

Maximum Steady State (MSS) Training

The easiest type of physiologically guided training to perform is maximal steady-state (MSS) training. You can do MSS training with any cyclic exercise modality, including cycling, running, rowing, or cross-country skiing.

You should begin exercising at a low to moderate intensity to find your maximal steady-state intensity. After an initial drop in your SmO2 level, it will stabilize. You should then increase your intensity ever so slightly. After seeing another drop in your SmO2, it should stabilize again, indicating that your body's oxygen supply systems can match your muscle's demand for oxygen.

After repeating this process, you will eventually find a power output where your SmO2 level does not stabilize after the initial drop and continues to decline steadily, indicating your working muscles are extracting oxygen faster than it can be supplied. At that point, you have overshot your MSS and should reduce your power or speed until your SmO2 level stabilizes. They should then aim to hold that approximate power output for the duration of the exercise bout, making minor modifications to avoid your SmO2 level declining. As your fitness improves, you should be able to hold progressively higher power outputs at your maximal steady state.

Rapid Desaturation Training

Mitochondria are best known as the powerhouse of cells due to their ability to generate chemical energy in the form of ATP. As a result, Mitochondria play a crucial role in cellular function and exercise performance, and athletes across various sports require time-efficient training methods to improve their mitochondrial density and muscle oxidative capacity.

Rapid desaturation training is designed to increase tissue capillarization, mitochondrial density, and an athlete's maximal rate of oxygen utilization. This training method must be performed at a near-maximal intensity with an interval long enough for muscle oxygen saturation to reach a minimum value.

Additionally, the total number of sets for this workout style should be individualized based on an athlete's real-time physiologic response. For example, we want an athlete to perform as many sets of rapid desaturation training as possible until they can no longer deoxygenate the working muscle to the same nadir as previous sets or they cannot recover their muscle oxygenation back to the same baseline level during fixed-duration rest periods.

Try it yourself!

Below is a sample rapid desaturation training session for a competitive Crossfit athlete during their offseason.

Accumulate as many rounds as possible: 10-second Echo Bike (70-75% of maximum wattage), Rest 1:00 b/w sets. The session ends when SmO2 cannot reach the same minimum value as previous sets during your sprint, or you cannot reoxygenate back to the same SmO2 value as previous sets during your recovery. Additionally, you should terminate the workout if you can no longer hit the prescribed wattage, you begin to compensate biomechanically to reach your target power, or your RPE increases exponentially from set to set.

This type of workout can also be completed with a concept-2 rower at 80-85% max watts or a skierg at 90-95% max watts. The target wattages are a starting point, and an individual may need to raise or lower them to achieve the target response. Additionally, I recommend putting a thirty to forty-five-minute time cap on this style workout to limit total training volume. If an athlete can reach the thirty or forty-five-minute mark, then I'll increase their power output the next time they complete this style workout.

Extended Desaturation Training

One of the most important considerations when training respiratory-limited athletes is that the amount of work accumulated at a high percentage of their peak oxygen consumption is a primary determinant of performance. However, the amount of training volume an athlete's muscles, bones, and joints can tolerate week after week is finite, limiting how much work they can conceivably do at a high percentage of their peak oxygen consumption.

One way to circumvent the issues above is to perform extended desaturation intervals. Extended desaturation intervals induce higher mean oxygen consumption levels than traditional interval training methods, making them ideal for accumulating more time at a high percentage of an athlete's VO2 peak with less wear and tear.

Extended desaturation intervals aim to have an athlete exercise at a high intensity, with a fixed power output, that causes them to utilize oxygen in the working muscles at a greater rate than it can be supplied, resulting in rapidly declining muscle oxygenation levels. Once muscle oxygenation stops declining and plateaus at a nadir, the athlete should stop exercising and begin their rest period. They should then rest until SmO2 stops increasing and levels off at a peak value, then repeat this process for two to six total sets. You can try this workout style with any cyclic exercise modality and should aim to use a power output, or pace, that allows you to sustain each effort for two to six minutes.

Try it yourself!
Below is a sample extended desaturation training session for a competitive rower. You can try this style of workout with any cyclic exercise modality, and should aim to use a power output, or pace, that allows you to sustain each effort for two to six minutes.

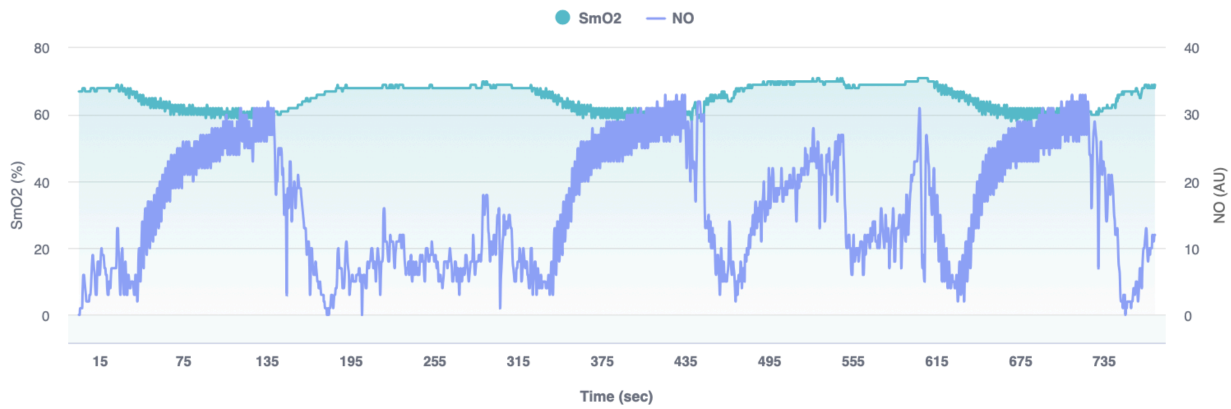
Row at 1:30/500m (5s/500m faster than 2k PR pace) until SmO2 stops declining and levels off at the same % for 5-10 seconds. Rest until SmO2 stops increasing and reaches a recovery baseline. Repeat for 2-6 total sets.

Gradual Desaturation Training

When you exercise, oxygen levels in the working muscles decline, causing nitric oxide (NO) to be released from red blood cells and signaling for small blood vessels to dilate. When small blood vessels dilate, the heart must stretch and pump harder and faster to maintain blood pressure. When done frequently enough, this type of training causes your heart to adapt, resulting in increased cardiac output.

To maximize your cardiac output, you can perform workouts that progressively deoxygenate your exercising muscles to a minimum oxygenation (SmO2) level, resulting in NO levels reaching their peak concentration. During these workouts, your heart will progressively pump harder and faster, up to its tolerable limits. At that point, you'll achieve peak cardiac output levels.

Once your muscle oxygenation (SmO2) is no longer declining and nitric oxide (NO) levels are no longer increasing, you should cut your work interval short. In the image below you can see an athlete's SmO2 and NO levels during three gradual desaturation intervals on a concept 2 rower.



I recommend that athletes performing gradual desaturation training aim for 2:00-6:00 of work per interval. You can repeat this process 3-6 times in a workout, resting 3:00-5:00 between sets.

Try it yourself!
Below is a sample gradual desaturation training session for a competitive Crossfit athlete. You can test this type of workout with any cyclic exercise modality, such as running, rowing, or cycling.

6:00 Echo Bike, Rest 4:00 x4 sets. Start each set at 150 watts (easy pace) and gradually increase your speed across the interval to finish within 5-10% of your minimum SmO2 value. Some gamification is needed to get the pacing just right, so you can experiment with different strategies for increasing your pace set to set.

Active Recovery

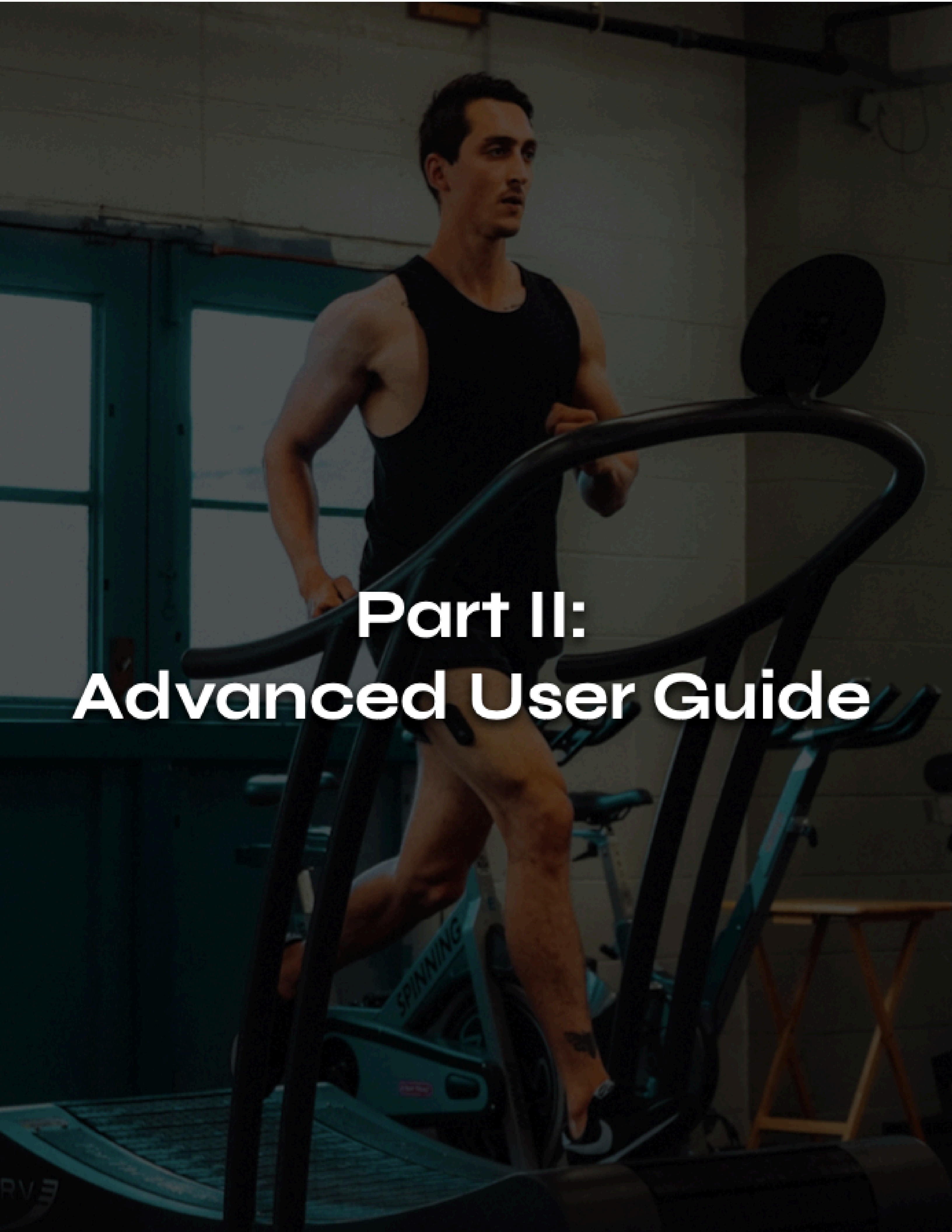
During active recovery training, the goal is to increase an athlete's SmO2 as much as possible, which will help aid in recovery. Because every athlete's physiology and response to exercise are unique, their active recovery sessions will also need to be. For example, many strong and muscular athletes have trouble doing true low-intensity work. In these groups, heart rate is not a reliable indicator of how much stress they impose on a given activity. When SmO2 is low, oxidative metabolism is compromised, which leads to an increased reliance on glycolysis to replenish phosphocreatine and, subsequently, ATP.

Athletes will find certain modalities where they cannot exercise without rapidly deoxygenating the working muscles. For example, many athletes cannot run with a stable or increasing SmO2 level and will have to walk to achieve that goal. So, the goal for each athlete is to find the right combination of modality, intensity, and cadence that allows them to maximize their SmO2 level over time during active recovery workouts.

Try it yourself!

Select a cyclic exercise modality, such as walking, running, cycling, or rowing. Then place your NNOXX device on your outer quadriceps muscle and record data using the unguided workout mode in NNOXX's mobile app.

Now, begin exercising at a very low intensity. Initially, you may see a slight decrease in SmO2, followed by a stabilization and slow rise. If SmO2 plateaus for more than three minutes, you can try modulating your power or speed to see if you can drive it up further. Counterintuitively, you may be able to drive your muscle oxygenation value up by increasing your speed every so slightly, then taking a brief rest period before continuing to exercise. You can also try increasing or decreasing your cadence without changing your power output. Over time, you'll identify patterns and learn how to best increase your muscular oxygenation value during active recovery sessions by choosing the correct exercise modality, intensity level, and cadence.



Part II: Advanced User Guide

Chapter 7- Tracking Changes in fitness and physiology

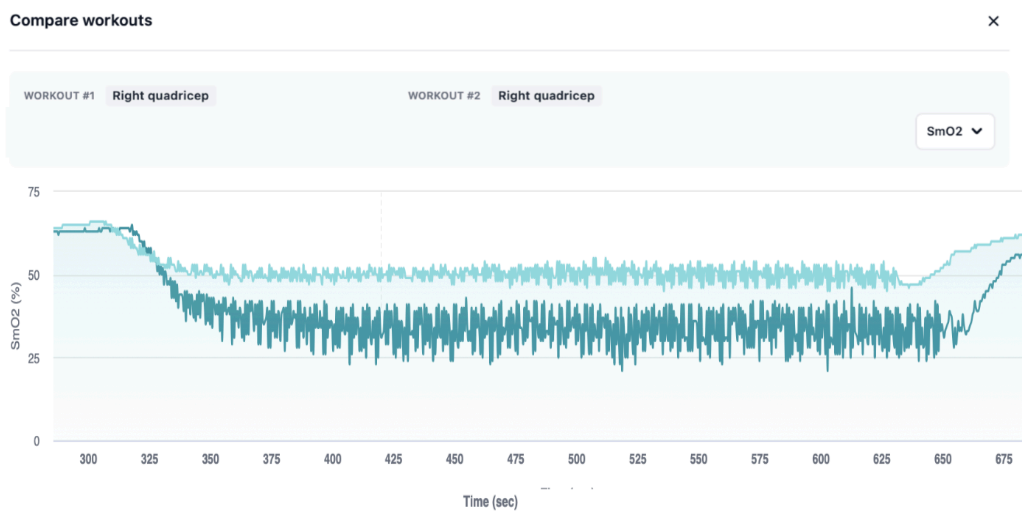
Traditional laboratory-based fitness assessments, such as VO2max testing, offer a limited snapshot of an athlete's fitness and performance. For example, day-to-day variability in an athlete's fatigue levels, motivation, and other performance-impacting factors may lead them to believe they are more or less fit than they are based on a single test's data. Additionally, the results from in-lab testing don't always translate well to real-world environments, making it challenging to extract usable insights from these testing procedures.

The advantage of wearable technology is that you can collect biomarker and performance data on continuous day-to-day data and in real-world environments, providing a more accurate view of how an athlete's fitness and physiology change over time.

In addition to monitoring your biomarkers and helping you guide training in real-time, NNOXX allows you to perform comprehensive post hoc data analysis using our web-based high-performance platform. Anytime NNOXX One elite users collect data in real-time using NNOXX's mobile app, it will automatically appear in their high-performance platform dashboard, making it easy to analyze and extract insights, such as how an athlete adapts to training and progresses over time. In the subsections below, you'll learn three different methods for tracking changes in your fitness and physiology over time using NNOXX's high-performance platform.

Tracking Changes In Fitness and Physiology - Beginner

The simplest, and easiest, way to track changes in an athlete's fitness from one week to another with the NNOXX high-performance platform is have them perform a fixed work bout on two different weeks while comparing their muscle oxygenation and nitric oxide levels. For example, the image below shows an athlete's muscle oxygenation (SmO2) level while performing a five minute bike interval at 300 watts on two different weeks. The first week's data is in dark blue, and the second week's data is in light blue.



During the first week, the athlete's average muscle oxygenation level during this five minute cycling bout at 300 watts was approximately 32%. During the second week, the athlete repeated the same cycling bout, but their average muscle oxygenation level was approximately 51%, meaning they produced the same amount of power while using less energy, which is a sign of increased fitness.

Try it yourself!

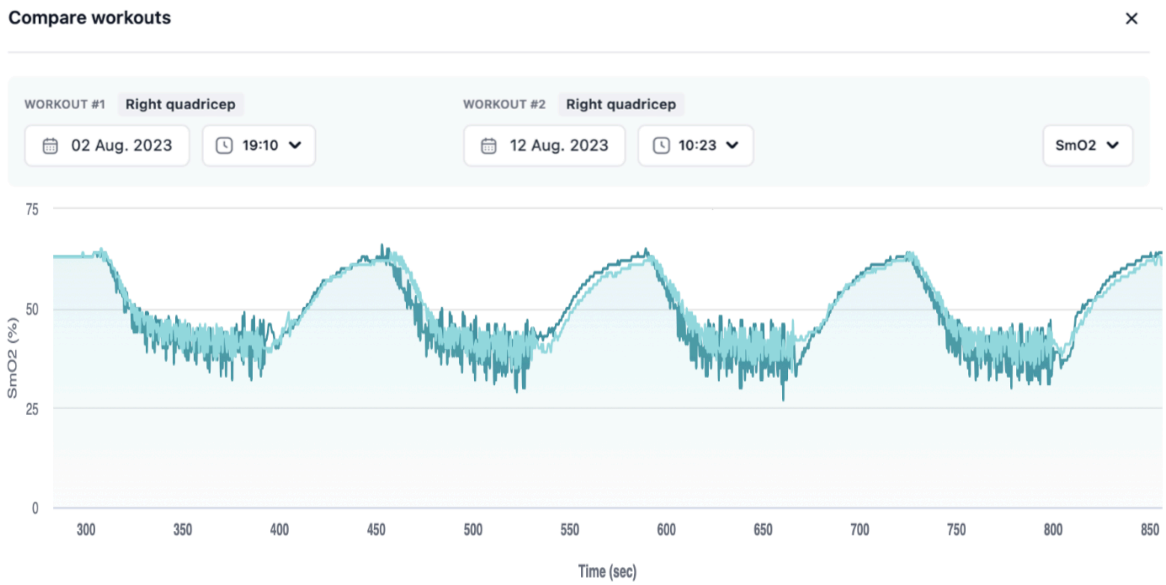
The best way to learn is through experience. Select a cyclic exercise modality, such as running, cycling, or rowing. Then place your NNOXX device on your outer quadriceps muscle and record data using the unguided workout mode in NNOXX's mobile app.

Now, select a power output (or speed) and duration for your exercise bout and record data for that workout. For example, a one mile run at a 7:00 mile pace and. After completing your workout NNOXX One Elite users can view their data in NNOXX's high-performance portal.

Repeat this same workout in a few days, and compare the two sessions data with the compare workout feature in the high-performance portal. If you muscle oxygenation higher or lower the second time? What about your nitric oxide level? What could these differences mean about your fitness level or recovery from one week to the next?

Tracking Changes In Fitness and Physiology – Intermediate

Another way to assess changes in an athlete's fitness from one week to another is to have them perform physiologically guided training while comparing their power output, speed, or performance between weeks.



In the image above you can see an athlete's muscle oxygenation (SmO2) levels on two different days where they performed four sets of a half-mile bike interval at 30-40% SmO2. On both training days the athlete was instructed to go as fast as possible while keeping their SmO2 level within the aforementioned range. The first week the athlete was able to hold 325 watts on their bike while keeping their muscle oxygenation level between 30-40%, and the second training week they were able to hold 350 watts while staying in this same SmO2 range. The ability to hold a higher power output at a given muscle oxygenation level is a strong indicator of increased fitness and performance. In practice coaches can use this information to determine whether an athlete's fitness is improving from one week to the next, which can help them determine if and when they need to modify an athlete's training plan to avoid plateaus.

Chapter 8- Identifying Physiological Limitations

NNOXX implements evidence-based frameworks to identify an individual's physiological limitations and provide personalized exercise recommendations to enhance performance. Knowing an athlete's physiological or bioenergetic limitation allows you to make informed decisions about what training they need to improve their short and long-term performance.

Physiologic limitations are rate-limiting factors for increasing an athlete's VO2 max, which represents the maximal integrated capacity of the pulmonary, cardiovascular, and muscle systems to uptake, transport, and utilize oxygen, respectively. Knowing an athlete's physiologic or bioenergetic limitation is often more important than knowing their absolute VO2 max value. The former tells you what type of training will best increase an athlete's performance, whereas the latter is used to characterize their performance potential.

NNOXX users can easily identify physiologic and bioenergetic limitations when used with other basic testing equipment. By doing so, NNOXX can help users determine what style and intensity of training will be most effective for increasing their VO2 max and improving their performance.

What Are The Most Common Physiological Limitations?

As previously stated, physiologic limitations are rate-limiting factors for increasing an athlete's VO2 max, which represents the maximal integrated capacity of the pulmonary, cardiovascular, and muscle systems to uptake, transport, and utilize oxygen, respectively. Thus, respiratory, cardiovascular, and muscular limitations are the three most common physiological limitations.

Among elite endurance athletes, respiratory limitations are the most common bioenergetic limiter. While most systems in the body undergo substantial adaptations to intense exercise, this doesn't appear to be the case for the respiratory system. Respiratory-limited athletes often present with above-average maximal cardiac output, high mitochondrial density, and high capillary density. As a result, these individuals have well-developed oxygen transport systems and a high maximal rate of oxygen utilization in the primary working muscle groups for their sport. However, these athletes are limited by the strength or fatigue resistance of their inspiratory muscles, expiratory muscles, and diaphragm. During high-intensity exercise, the diaphragm has a large energy requirement and will be required to contact with high force and frequency. When the diaphragm muscle begins to fatigue, locomotor muscle oxygenation will decrease, as will the amount of carbon dioxide an athlete can expel. In extreme cases, athletes present with hypoxemia, defined by a large decrease in arterial oxygen saturation levels as measured with a pulse oximeter. I've previously observed arterial oxygen saturation levels >15% below resting values during maximal effort exercise, which indicates a pulmonary diffusion limitation and lack of respiratory muscle endurance.

It's common for respiratory-limited athletes to have a low forced vital capacity and functional lunge volume relative to their body mass. Additionally, basic spirometry measurements can be used to discern between inspiratory and expiratory muscle limitations. An athlete with weak inspiratory muscles will have a lower forced vital capacity (FVC6) and a low forced expiratory volume (FEV1), but the ratio between the two will be between 76-80%. An athlete with weak expiratory muscles will also have a low FVC6 and FEV1, but the ratio between the measurements will be below 76%.

In addition to respiratory limitations, which limit the rate of oxygen uptake, cardiovascular limitations can also limit oxygen supply to the working muscles. From here out, I'll refer to cardiovascular limitations as delivery limitations since they limit an individual's ability to deliver oxygenated blood to the working muscles. Exercisers with delivery limitations often have high maximal rates of oxygen extraction and are limited by the maximal pumping capacity of their heart during exercise, which limits their peripheral blood flow. As a result, oxygen utilization in the working muscle supersedes oxygen supply, resulting in very low muscle oxygenation levels when task failure occurs.

Strong, heavily-muscled athletes with great local and regional muscular endurance often present with delivery limitations. As a result, they struggle with tests of systemic work capacity that utilize a large percentage of total skeletal muscle mass. For example, among competitive Crossfit athletes, you'll often find individuals who can perform very large unbroken sets of ring muscle-ups, handstand pushups, and chest-to-bar pull-ups in isolation and when non-fatigued. However, pairing the movements above with other full body exercises in a metcon, they'll often struggle to complete even the smallest sets unbroken without getting 'pumped up'. This occurs because delivery-limited athletes have lowered maximal cardiac outputs. As a result, they are limited in the total amount of skeletal muscle they can vasodilate at any given moment. This is problematic when they are forced to alternate exercising muscle groups, resulting in severe extremity muscle deoxygenation.

Oxygen utilization limitations differ from respiratory and delivery limitations in that exercisers with this form of limitation can supply a sufficient amount of oxygen to the working muscles. Creating a representative avatar of a utilization-limited athlete is difficult because the underlying causes of utilization limitations are so broad. For example, utilization limitation can be caused by insufficient mitochondrial or capillary density, excessive muscle damage, impaired muscle coordination and recruitment, or changes in blood chemistry.

Additionally, exercisers with utilization limitations may be limited by their maximal rate of oxygen utilization, the magnitude of oxygen utilization in the working muscles, or both. Given the range of ways that utilization limitations can present themselves, there are few broadly applicable global adaptation trends. However, some commonalities among utilization-limited athletes are lowered rate of force development, a low maximal power output relative to their critical power, poor skeletal muscle recruitment, and impaired metabolic activity in peripheral tissues.

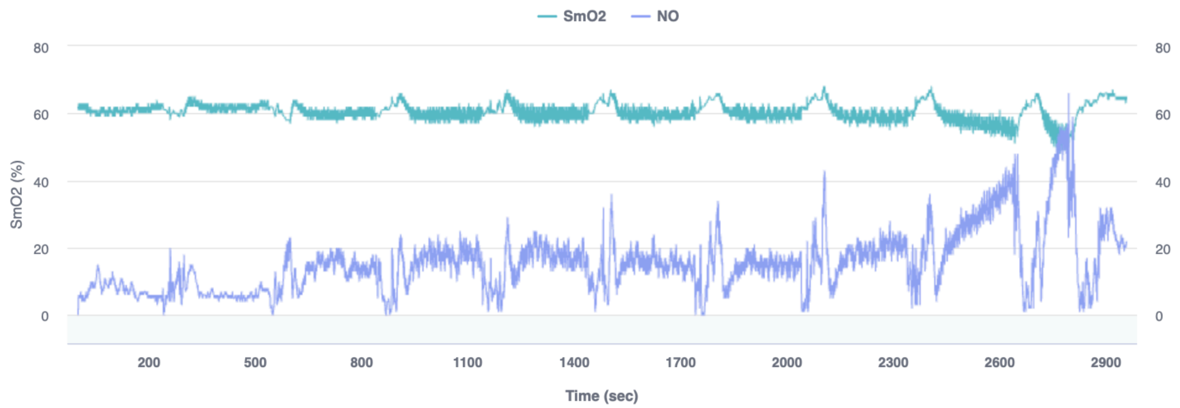
How to identify Physiological Limitations?

Since physiologic limitations are rate-limiting factors for increasing an athlete's VO2 max, the same rules and best practices that apply to VO2 max testing will also apply to identifying an athlete's limiter. For example, athletes should select exercise modalities they are well trained on that utilize a significant amount of their total skeletal muscle mass; otherwise, they will not be able to achieve a true VO2 max.

After selecting an appropriate exercise modality, NNOXX users should wear their NNOXX on a primary locomotor muscle. The vastus lateralis (outer quadricep) is the most reliable measurement location for activities such as cycling, rowing, or running. However, it should be understood that there is a heterogeneity of responses across different muscle sites. As a result, understanding complex whole-body physiological responses warrants the use of multiple NNOXX sensors to compare the following:

1. Upper vs. lower body locomotor muscle responses: for example, measuring the vastus lateralis and bicep while rowing or doing Crossfit.
2. Two lower body locomotor muscle responses: for example, measuring the vastus lateralis and rectus femoris while cycling.
3. Locomotor vs. Non-locomotor muscle responses: for example, comparing the vastus lateralis and forearm while running.

Finally, NNOXX users should select a standardized exercise test to identify their physiologic limitations - the ideal test will depend on the athlete's training history, sports demands, and modality. The most common type of physiologic assessment is a ramp incremental exercise test with three to ten-minute load steps. Importantly, exercisers should begin the test at a very low intensity, and build to a maximal effort over a twenty to sixty-minute period, allowing them to see how their body responds to a wide range of exercise intensities, as demonstrated in the image below. Advanced athletes may also wish to use time trials, or simulated competitions, as part of their physiologic assessment process.



Try it yourself!
Select a cyclic exercise modality, such as walking, running, cycling, or rowing. Then place your NNOXX device on your outer quadriceps muscle and record data using the unguided workout mode in NNOXX's mobile app. Below you'll find an exemplar ramp incremental exercise test for an elite female Crossfit athlete.

5:00 Echo Bike @ 125 watts
Rest 1:00
5:00 Echo Bike @ 175 watts
Rest 1:00
5:00 Echo Bike @ 225 watts
.... Continuing until task failure occurs.

Athlete's are instructed to record their heart rate throughout the test and their blood oxygenation (SpO2) between load steps. Advanced athlete's can also benefit from recording their VO2 with a metabolic analyzer throughout and taking blood lactate (BLa) measurements between load steps.

Analyzing Data to identify limiters

After athletes perform a physiological assessment using the unguided workout feature in the NNOXX mobile app, they can analyze their data using NNOXX's web-based High-Performance Platform. When analyzing their workout data, athletes should be looking for indications of delivery, respiratory, and utilization limitations. Where applicable, athletes and coaches may also want to cross-reference their NNOXX data against other physiologic or performance metrics to provide additional information to help identify a limiter or individualize an athlete's training program.

As mentioned earlier in this chapter, respiratory-limited athletes have well-developed oxygen transport systems and a high maximal rate of oxygen utilization in the primary working muscle groups for their sport. However, these athletes are limited by the strength of their inspiratory or expiratory muscles or their diaphragm's fatigue resistance. Respiratory-limited athletes may also present with a pulmonary diffusion limitation, resulting in arterial hypoxemia during long-duration maximal effort exercise.

Because respiratory limitations are a form of oxygen supply limitation, we should expect a progressive decline in muscle oxygenation (SmO2) until task failure occurs. Additionally, we should expect a meaningful decrease in blood oxygenation (SpO2) from rest to failure in respiratory-limited athletes. However, since cardiac output is not the primary performance limitation, we will often see nitric oxide (NO) levels and heart rate increase until task failure occurs, as demonstrated below. Additional information can also be gleaned from VO2 measurements and spirometry, helping to identify respiratory limitations. For example, an athlete's VE:VO2 ratio should be consistent and stable between load steps in a ramp incremental exercise test. However, respiratory-limited athletes often see their VE:VO2 ratio spike upwards under heavy fatigue, indicating a sudden drop in breathing efficiency as their diaphragm muscle fatigues. Additionally, basic spirometry measurements can be used to differentiate inspiratory and expiratory muscle limitations. An athlete with weak inspiratory muscles will have a lower forced vital capacity (FVC6) and a low forced expiratory volume (FEV1), but the ratio between the two will be 76-80%. An athlete with weak expiratory muscles will also have a low FVC6 and FEV1, but the ratio between the measurements will be below 76%.

Like respiratory-limited athletes, delivery-limited athletes have an oxygen supply limitation, and, as a result, they experience a progressive decline in muscle oxygenation (SmO2) until task failure occurs. However, where delivery-limited athletes differ is that they generally experience a plateauing of their heart rate or nitric oxide levels above 85% of their VO2 max or before task failure occurs.

Oxygen utilization limitations differ from respiratory and delivery limitations in that athletes with this limitation can supply a sufficient amount of oxygen to the working muscles. As a result, they have elevated muscle oxygenation (SmO2) levels at task failure. Additionally, because muscle oxygenation levels do not meaningfully decline and often plateau well before task failure, utilization-limited athletes' nitric oxide measurements are less responsive and often plateau earlier into ramp incremental exercise tests. Finally, one of the defining traits of utilization-limited athletes is a lack of top-end speed and power, presenting as a 'fixed gear' athlete with a small range of speeds and power outputs accessible to them. However, they tend to excel at holding high percentages of their top end speed for long durations.

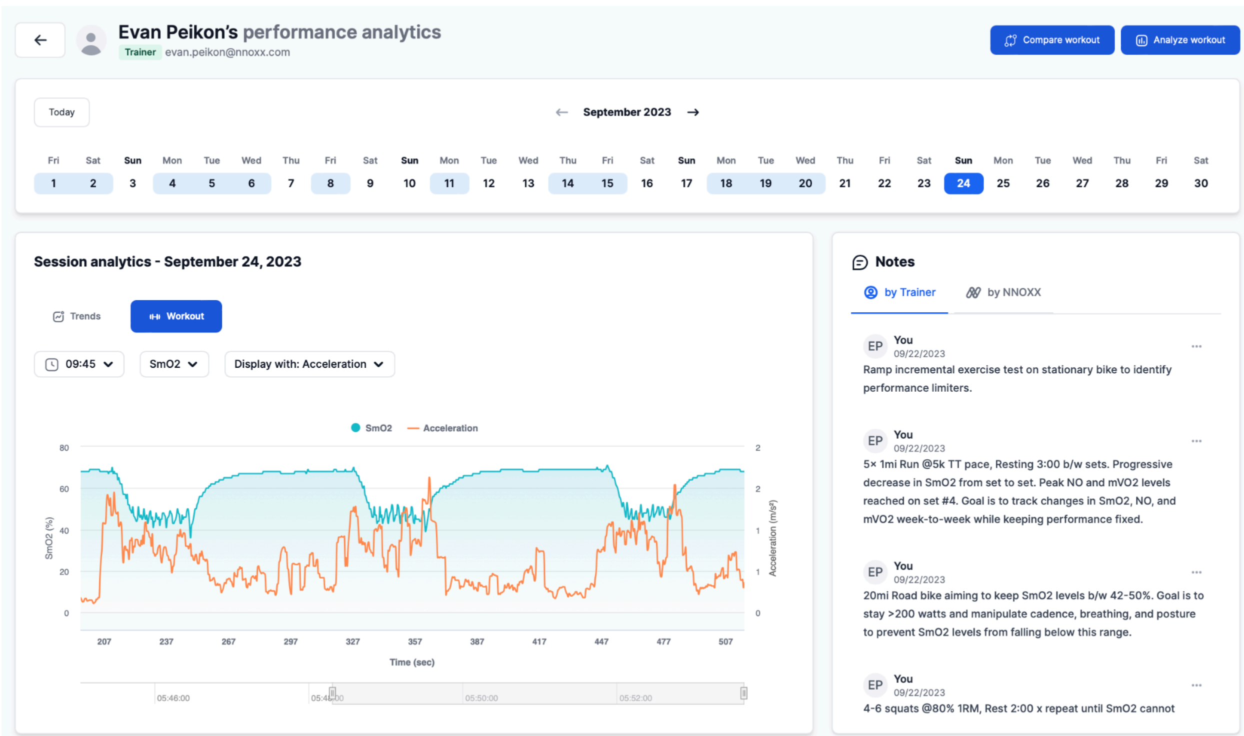
The image below summarizes some of the positive and negative characteristics that are often present in athletes with the three primary bioenergetic limitations. A given athlete may present with qualities that match all three of these avatars, and thus the goal is to determine which limiter, or combination of limiters best matches a given athlete's data.

	Delivery Limited	Respiratory Limited	Utilization Limited
Muscle Oxygenation (SmO_2)	-Rapid drop upon start of exercise -Progressive decline until volitional failure or just prior to volitional failure occurring -Moderate to large range in SmO_2 values (sport dependent)	-Rapid drop upon start of exercise -Progressive decline until volitional failure or just prior to volitional failure occurring -Moderate to large range in SmO_2 values (sport dependent)	-Minor drop upon start of exercise -Progressive, but limited, decline during exercise followed by plateau before volitional failure. -Small range in SmO_2 values
Nitric Oxide (NO)	-Rapid increase upon start of exercise -Progressive increase until ~85-90 max heart rate.	-Rapid increase upon start of exercise -Progressive increase until volitional failure, or just prior to volitional failure occurring	-Minor increase upon start of exercise -Progressive, but limited, increase until volitional failure or just prior to volitional failure occurring
Heart Rate (HR)	-Rapid increase upon start of exercise -Progressive increase until ~85% VO_2max	-Rapid increase upon start of exercise -Progressive increase until volitional failure, or just prior to volitional failure occurring	-Rapid increase upon start of exercise -Progressive increase until volitional failure, or just prior to volitional failure occurring
Blood Oxygenation (SpO_2)	-Stable values throughout exercise (+/- 1-3%)	-Stable values (+/- 1-3%) during low to moderate exercise. -Progressive decline above heavy to severe intensity domains	-Stable values throughout exercise (+/- 1-3%)
VO_2	-Stable $VE:VO_2$ ratio	-Stable $VE:VO_2$ ratio at low to moderate intensities -Increasing $VE:VO_2$ ratio above heavy to severe intensity domains	-Stable $VE:VO_2$ ratio
Spirometry	-FVC6 >= BW(kg)/13.6-13.8 -FEV1 >= BW(kg)/17.1-17.3	-FVC6 < BW(kg)/13.6-13.8 -FEV1 < BW(kg)/17.1-17.3 -If FVC6 and FEV1 are low, but FEV1 >75% FVC6 it may indicate an inspiratory muscle limitation. If FEV1 is < FVC6 it may indicate an expiratory limitation.	FVC6 >= BW(kg)/13.6-13.8 -FEV1 >= BW(kg)/17.1-17.3
Performance Characteristic	-High top end speed/power, but lacks speed endurance -Easily 'pumped' during high intensity exercise -Excels at shorter distances/durations, but struggles with longer events	-Balanced speed/power and endurance -Experiences visual tunneling or numbness in fingers/toes during maximal effort exercise bouts -Excels at middle distance events	-Single gear athlete. Similar paces across distances of varying durations -Lacks top end speed/power, but has good speed endurance at high %'s of max speed/power -Excels at longer distances

Part V: Expert User Guide

Chapter 9- Assessing Physiological Responses To Exercise (Advanced Data Interpretation)

The NNOXX wearable provides users with the power of an exercise physiology lab in a compact, pocket-sized, device, allowing them to assess their body's physiological response to exercise. With this innovative tool, users have the freedom to collect data anywhere and during any activity, ensuring that the insights gathered are both accurate and relevant to real-world conditions. In order to facilitate this process, NNOXX developed the High Performance Platform (HPP), enabling users to perform in-depth data analysis at their convenience. In NNOXX's HPP, you can view your muscle oxygenation (SmO2), nitric oxide (NO), oxygen consumption (mVO2), acceleration, and skin temperature data captured with the NNOXX wearable device.



Continuous Cyclic Exercise

To interpret your biomarker data during continuous cyclic exercise you should follow the steps outlined below:

- **Step 1 -** Slice the workout into segments based on distinct patterns in your acceleration, muscle oxygenation (SmO2), and nitric oxide (NO) data. A segment consists of a period in the workout where the trends for all three measurements above are relatively unidirectional. For example, a period in which acceleration increases, SmO2 decreases, and NO increases is a segment. Then, let's say acceleration becomes constant, SmO2 continues to decrease, and NO continues increasing - that is another segment.

- **Step 2 -** After breaking your workout into segments, you can interpret the data for each segment one by one using the look-up table provided in the guide below. The guide is broken into three parts based on whether acceleration is increasing, decreasing, or constant. Within each of those three parts, you'll find all possible combinations of SmO2 and NO trends with interpretations for what each of them means for you.
- **Step 3** - After analyzing each segment of your workout, you can order the interpretations sequentially, resulting in a time-series analysis of what happened during the workout (i.e., how acceleration, speed, or power changed as a function of time), how your body responded, and what this means.
-

Interval Cyclic Exercise

To interpret your biomarker data during interval cyclic exercise you should follow the steps outlined below:

- **Step 1-** Slice the workout into intervals based on your work and rest periods.
- **Step 2 -** After breaking your workout into discrete work and rest intervals, you can interpret your changes in measurements from each interval to the next using the look-up table provided in the guide below. For example, did acceleration, SmO2, and NO increase, decrease, or remain constant from one interval to the next?
- **Step 3 -** After analyzing each interval, you can order the interpretations sequentially, resulting in a time-series analysis of what happened during the workout (i.e., how acceleration, speed, or power changed as a function of time), how your body responded, and what this means.
- **Step 4 -** If you're interested in digging into your body's physiological response during each interval and how it changes, you can use the continuous cyclic exercise guide above, treating an interval as a discrete-continuous work bout.

I *increased* my acceleration, speed, or power... Now, what does my data mean?		
How Did Your Body Respond?		**What Does It Mean?**
Decreased SmO2	**Increased NO**	You increased your speed, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable for an extended duration.

		Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of increased NO and decreased SmO2 means that you utilized an increased fraction of an increased oxygen supply to power activity as intensity increases. This is a typical physiological response during high-intensity exercise.
Decreased SmO2	**Decreased NO**	You increased your speed, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable for an extended duration. Furthermore, nitric oxide (NO) levels decreased, resulting in diminished blood flow and oxygen delivery to tissues. The combination of decreased SmO2 and NO means you utilized an increased fraction of a decreasing oxygen supply to power activity as intensity increases, indicating you may benefit from training that improves your maximal cardiac output, blood flow, and oxygen supply to exercising muscles.
Decreased SmO2	**Constant NO**	You increased your speed, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable for an extended duration. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of decreased SmO2 and stable NO means you utilized an increased fraction of a constant oxygen supply to power activity as intensity increases, indicating you may benefit from training that improves your maximal cardiac output, blood flow, and oxygen supply to exercising muscles.
Increased SmO2	**Increased NO**	You increased your speed, and your body responded by utilizing less of the oxygen available to your muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles is greater than the oxygen demand in your muscles, and your power output is sustainable despite increasing. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of increased SmO2 and increased SmO2 means that you utilized a decreased fraction of an increased oxygen supply to power activity as intensity increases. These trends indicate that you may have altered your movement pattern to reduce local muscle fatigue. Alternatively, you may observe these trends during a warmup period.
Increased SmO2	**Decreased NO**	You increased your speed, and your body responded by utilizing less of the oxygen available to the muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles was greater than the oxygen demand in your muscles, and your power output was sustainable despite increasing. Furthermore, nitric oxide (NO) levels decreased, resulting in diminished blood flow and oxygen delivery to tissues. The combination of increased SmO2 and decreased NO means

		that you utilized a decreased fraction of a decreasing oxygen supply to power activity as intensity increases. These trends indicate that you may have altered your movement pattern over the course of the workout to reduce muscle fatigue.
Increased SmO2	**Constant NO**	You increased your speed, and your body responded by utilizing less of the oxygen available to the the muscle to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles was greater than the oxygen demand in your muscles, and your power output is sustainable despite increasing. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of increased SmO2 and stable NO means that you utilized a decreased fraction of a constant oxygen supply to power activity as intensity increases. These trends indicate that you may have altered your movement pattern to reduce muscle fatigue.
Constant SmO2	**Increased NO**	You increased your speed and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of stable SmO2 and increased NO means that you utilized a constant fraction of an increased oxygen supply to power activity as intensity increases. Thus, even though SmO2 is unchanging, we can infer that your total oxygen consumption still increased, which is a common physiological response during moderate to high-intensity exercise.
Constant SmO2	**Decreased NO**	You increased your speed, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the oxygen supply to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels decreased, reducing blood flow and oxygen delivery to tissues. The combination of stable SmO2 and decreased NO means that you utilized a constant fraction of a decreasing oxygen supply to power activity as intensity increases. Thus, even though SmO2 is unchanging, we can infer that your total oxygen consumption decreased, which indicates that you may have altered your movement pattern to reduce local muscle fatigue as power output increased.
Constant SmO2	**Constant NO**	You increased your speed, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the oxygen supply to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of stable SmO2 and NO means that you utilized a constant fraction of a constant oxygen supply to power activity as intensity increases. Thus, even though intensity increases, we can infer that your body sufficiently coped with the demand, maintaining homeostasis.

I *decreased* my acceleration, speed, or power… Now, what does my data mean?		
How Did Your Body Respond?		**What Does It Mean?**
Decreased SmO2	**Increased NO**	You decreased your speed, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable despite the intensity decreasing. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of decreased SmO2 and increased NO means you utilized an increased fraction of an increased oxygen supply to power activity, even as intensity decreases. This is a typical physiological response during high-intensity exercise.
Decreased SmO2	**Decreased NO**	You decreased your speed, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable despite the intensity decreasing. Furthermore, nitric oxide (NO) levels decreased, resulting in diminished blood flow and oxygen delivery to tissues. The combination of decreased SmO2 and NO means you utilized an increased fraction of a decreasing oxygen supply to power activity, even as intensity decreases. This indicates you may benefit from training that improves your maximal cardiac output, blood flow, and oxygen supply to exercise muscles.
Decreased SmO2	**Constant NO**	You decreased your speed, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable despite the intensity decreasing. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of decreased SmO2 and stable NO means you utilized an increased fraction of a constant oxygen supply to power activity, even as intensity decreases, indicating you may benefit from training that improves your maximal cardiac output, blood flow, and oxygen supply to exercising muscles.
Increased SmO2	**Increased NO**	You decreased your speed, and your body responded by utilizing less of the oxygen available to your muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles is greater than the oxygen demand in your muscles, and your power output is sustainable. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen

		delivery to tissues. The combination of increased SmO2 and increased SmO2 means that you utilized a decreased fraction of an increased oxygen supply to power activity as intensity decreases. These trends may indicate recovery as your speed or power output decreases.
Increased SmO2	**Decreased NO**	You decreased your speed, and your body responded by utilizing less of the oxygen available to your muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles is greater than the oxygen demand in your muscles, and your power output is sustainable. Furthermore, nitric oxide (NO) levels decreased, resulting in diminished blood flow and oxygen delivery to tissues. The combination of increased SmO2 and decreased NO means that you utilized a decreased fraction of a decreasing oxygen supply to power activity as intensity decreases. These trends may indicate recovery as your speed or power output decreases.
Increased SmO2	**Constant NO**	You decreased your speed, and your body responded by utilizing less of the oxygen available to your muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles is greater than the oxygen demand in your muscles, and your power output is sustainable. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of increased SmO2 and stable NO means that you utilized a decreased fraction of a constant oxygen supply to power activity as intensity decreases. These trends may indicate recovery as your speed or power output decreases.
Constant SmO2	**Increased NO**	You decreased your speed, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of stable SmO2 and increased NO means that you utilized a constant fraction of an increased oxygen supply to power activity as intensity decreases. Thus, even though SmO2 is unchanging, we can infer that your total oxygen consumption still increased, which is a common physiological response during moderate to high-intensity exercise.
Constant SmO2	**Decreased NO**	You decreased your speed, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels decreased, reducing blood flow and oxygen delivery to tissues. The combination of stable SmO2 and decreased NO means that you utilized a constant fraction of a decreasing oxygen supply to power activity as intensity decreases. Thus, even though SmO2 is unchanging, we can infer that your total oxygen consumption

		decreased. This is a sign that you're recovering as you decrease your power output or that you altered your movement pattern to reduce local muscle fatigue.
Constant SmO2	**Constant NO**	You decreased your speed, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of stable SmO2 and NO means that you utilized a constant fraction of a constant oxygen supply to power activity as intensity decreases. Thus, even though intensity decreases, it is not low enough for you to fully recover, instead resulting in the maintenance of your internal physiologic state.

My acceleration, speed, or power were ***constant***... Now, what does my data mean?

How Did Your Body Respond?		What Does It Mean?
Decreased SmO2	**Increased NO**	Your speed was constant, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable despite the intensity decreasing. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of decreased SmO2 and increased NO means you utilized an increased fraction of an increased oxygen supply to power activity, even as speed is constant. This is a typical physiological response during high-intensity exercise.
Decreased SmO2	**Decreased NO**	Your speed was constant, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable despite the intensity decreasing. Furthermore, nitric oxide (NO) levels decreased, resulting in diminished blood flow and oxygen delivery to tissues. The combination of decreased SmO2 and NO means you utilized an increased fraction of a decreasing oxygen supply to power activity, even as speed is constant, indicating you may benefit from training that improves your maximal cardiac output, blood flow, and oxygen supply to exercising muscles.

Decreased SmO2	Constant NO	Your speed was constant, and your body responded by utilizing a greater % of the oxygen available to your muscles to power activity, resulting in a decreased muscle oxygen saturation (SmO2) level. Thus, oxygen demand in your exercising muscles is greater than oxygen supply, and we can infer that your level of exertion is unsustainable despite the intensity decreasing. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of decreased SmO2 and stable NO means you utilized an increased fraction of a constant oxygen supply to power activity, even as speed is held constant, indicating you may benefit from training that improves your maximal cardiac output, blood flow, and oxygen supply to exercising muscles.
Increased SmO2	Increased NO	Your speed was constant, and your body responded by utilizing less of the oxygen available to your muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles is greater than the oxygen demand in your muscles, and your power output is sustainable. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of increased SmO2 and increased SmO2 means that you utilized a decreased fraction of an increased oxygen supply to power activity as speed is held constant. These trends indicate that you may have altered your movement pattern to reduce local muscle fatigue or that movement efficiency has improved. Alternatively, you may observe these trends during a warmup period.
Increased SmO2	Decreased NO	Your speed was constant, and your body responded by utilizing less of the oxygen available to your muscles to power activity, resulting in an increased muscle oxygenation (SmO2) level. Thus, the oxygen supply to your muscles is greater than the oxygen demand in your muscles, and your power output is sustainable. Furthermore, nitric oxide (NO) levels decreased, resulting in diminished blood flow and oxygen delivery to tissues. The combination of increased SmO2 and decreased NO means that you utilized a decreased fraction of a decreasing oxygen supply to power activity as your speed is held constant. These trends indicate that you may have altered your movement pattern to reduce local muscle fatigue or that movement efficiency has improved. Alternatively, you may observe these trends during a warmup period.
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Constant SmO2	**Increased NO**	Your speed was constant, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels increased, resulting in greater blood flow and oxygen delivery to tissues. The combination of stable SmO2 and increased NO means that you utilized a constant fraction of an increased oxygen supply to power activity as your intensity is held constant. Thus, even though SmO2 is unchanging, we can infer that your total oxygen consumption still increased, which is a common physiological during moderate to high-intensity exercise.
Constant SmO2	**Decreased NO**	Your speed was constant, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels decreased, reducing blood flow and oxygen delivery to tissues. The combination of stable SmO2 and decreased NO means that you utilized a constant fraction of a decreasing oxygen supply to power activity as intensity is constant. Thus, even though SmO2 is unchanging, we can infer that your total oxygen consumption decreased. This may indicate improved recovery or efficiency at a constant speed, or that or that you altered your movement pattern to reduce local muscle fatigue.
Constant SmO2	**Constant NO**	Your speed was constant, and your body responded by utilizing a constant % of the oxygen available to your muscles to power activity. This means the supply of oxygen to your muscles and your muscle's demand for oxygen are balanced, resulting in a steady state. Furthermore, nitric oxide (NO) levels were stable, indicating a constant supply of blood and oxygen to working muscles. The combination of stable SmO2 and NO means that you utilized a constant fraction of a constant oxygen supply to power activity as intensity is held constant. From these trends we can infer you are at a metabolic steady-state and that your current power output is sustainable.