AN INTRODUCTION TO

METABOLIC ANALYSIS

A guide to understanding testing methods, metrics and the interpretation of findings.

Presented By:

VO2 MASTER

An Introduction To Metabolic Analysis

An eBook presented by VO2 Master Health Sensors Inc.

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Introduction

Welcome to An Introduction to Metabolic Analysis. In this ebook, you will discover a concise and clear overview of metabolic testing theory, terminology, and methods. In addition, you'll come to understand why this analysis is important, including how to best interpret and apply test results to optimize fitness training.

What is VO_2 Analysis?

If you're a professional coach, serious athlete or exercise scientist, you're probably looking at and evaluating ways to **run faster and farther, workout harder** and **push athletic limits.**

Your investigation may include tracking such parameters as heart rate, caloric burn and top speed; however, there's key fitness markers that your fitness watch can't tell you: **your VO_2 max** and **ventilatory thresholds** (VT1 and VT2). These parameters are useful physiological measures within the field of *metabolic testing.*

Your VO_2 max and ventilatory thresholds can provide you with **important insights about your cardiorespiratory fitness**, such as how long you can sustain a certain intensity of exercise – which, for example, directly relates to your mile run time.

What is VO_2 max?

Let's start with VO_2max and then discuss ventilatory thresholds.

VO_2 max is an abbreviated term for *maximal oxygen consumption*, which refers to **the maximum amount of oxygen that an individual can utilize during intense or maximal exercise.**

It's measured in millilitres of oxygen per kilogram of body weight per minutes (ml/kg/min) with essentially **two determining factors:**

• How much blood your heart can pump out to the muscles with each beat (cardiac output).

• How efficiently your muscles can extract the oxygen from the blood and utilize it.

This measurement is generally considered the **best indicator** of cardiovascular fitness and aerobic endurance. The more oxygen a person can use during high level exercise, the more energy a person can produce.

As such, this test is the **gold standard** for determining cardiorespiratory fitness because muscles need oxygen for prolonged aerobic exercise, and the heart must pump adequate amounts of blood through the circulation to meet the demands of aerobic exercise.

The bottom line is the higher your VO_2 max score, the more aerobic potential you have. However, with the right training, you can increase your VO_2 max. And perhaps more importantly, you'll be able to increase your efficiency at higher outputs of speed and power.

How do you test VO_2 max?

By putting a face mask on the person being tested (the subject), it's possible to directly measure the volume and gas concentrations of inspired and expired air. This breath-by-breath measurement is agreed upon by researchers as being the most accurate way to conduct VO_2 analysis.

The test involves exercising (often running or bicycling) at an intensity that increases every few minutes until exhaustion and is designed to achieve a maximal effort.

During this test, the individual's maximum heart rate is also determined which, along with resting heart rate, can be used to develop a more precise target heart rate ranges. This is more accurate than age- predicted equations.

As a result of this process, clear insight into the subject's current fitness level is ascertained along with information as to how to most efficiently improve their fitness level.

Up until recently, obtaining an accurate measure of one's VO_2 max wasn't easy – you needed to measure it in a lab with expensive clinical medical equipment. Thankfully, that's all changed now with the advent of the innovative VO2 Master Analyzer.

Training Intensities

Before we move on to discussing ventilatory thresholds, it's necessary to cover training intensities. Ventilation and heart rate serve as a good reference points for determining one's training intensity and, unlike power or speed, these measures show how intense the effort is on the body. The higher the value for each, the more stress is being placed on the body.

Training Zones

VO2 Master has defined five training zones defined by breathing rate and heart rate that categorize intensity levels.

• Zone 1: Rest

Zone 1 is the lowest intensity level where a person is at rest. At this level, heart rate is low and breathing rate may be somewhat irregular due to one shifting, yawning and slight movements.

• Zone 2: Mild

In this zone a person is moving, and may be walking, jogging or cycling at an easy pace. Here, heart rate begins to increase and breathing rate becomes very steady. A person can easily converse with others in this stage.

- **Zone 3: Moderate**

This zone is characterized by more effort and may include running or cycling at a relatively comfortable pace. Heart rate continues to increase in a linear fashion and breathing rate continues to be regular; however, the tidal volume has increased (the volume of air inhaled and exhaled per breath).

- **Zone 4: Heavy**

In this zone, a person is exercising at an intensity where they are breathing hard and are limited as to how long they can continue to move at this level. Lactate starts to climb, and the athlete is beginning to lose control of their breathing, as their breathing rate now increases significantly – a departure from the regular intervals of Zones 2 and 3. Heartrate continues to climb at a uniform level commensurate with applied exercise effort.

- **Zone 5: Maximum**

The topmost zone is where a subject loses control of their breathing entirely, with their breathing rate skyrocketing. They will only be able to stay in this stage for a short period of time – up to 2 minutes. Heart rate will hit its maximum as the person tries to hang on, before inevitably dropping out of this level of intensity.

Ventilatory Threshold Testing

Now that we have defined the five intensity training zones, we can look to two points of interest, around which training zones are organized for an individual – ventilatory thresholds.

Ventilatory threshold testing is based on the physiological principle of ventilation. During lower stages of exercise intensity (Zones 2 and 3), ventilation increases linearly with oxygen consumption and carbon dioxide production. This occurs primarily through an increase in tidal volume.

At higher intensities (Zones 4 and 5), the frequency of breathing becomes more pronounced and minute ventilation (measured as the volume of air breathed per minute) rises disproportionally to the increase in oxygen consumption. This means that persons at these higher levels begin to breathe more rapidly with each breath consuming less oxygen.

As exercise intensity increases, ventilation increases in a somewhat linear fashion. Now, there two deflection points at certain intensities associated with the metabolic changes occurring within the body.

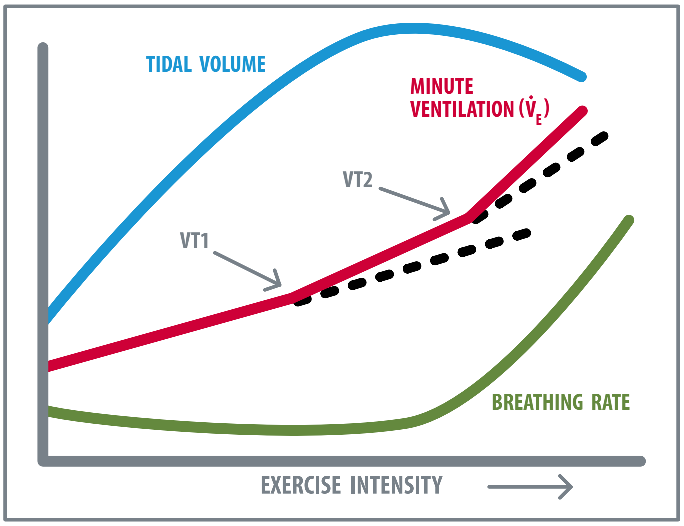
The first point – **Ventilatory Threshold 1** (or VT1) – is called the "crossover" point and occurs between Zone 3 and Zone 4.

This point is where blood lactate accumulates faster than it can be cleared, which causes a person to breathe faster in order to blow off the extra CO_2 produced by the buffering of acid metabolites. Prior to this intensity, fats are the major source of fuel and only small amounts of lactate are being produced. The need for additional oxygen here is met primarily through an increase in tidal volume and not by breathing faster. In other words, at this point, a person's breathing rate remains steady – they just take in more oxygen per breath.

Past the crossover point (VT1), ventilation rates will begin to increase exponentially as oxygen demands outpace the oxygen-delivery system and lactate begins to accumulate in the blood.

Eventually, the person will approach the second disproportionate increase in ventilation – the second **Ventilatory Threshold 2** (VT2), which occurs between Zones 4 and 5, at the point where lactate is increasing with intensity and represents hyperventilation. This represents the point where blowing off CO_2 is no longer adequate to buffer the increase in acidity that is occurring with progressively intense exercise.

FIGURE 1.0 *Ventilatory affects during aerobic exercise.*



VT1 = First ventilatory threshold
VT2 = Second ventilatory threshold

The VT1 to VT2 Distance

The longer a person can stay in the stretch between VT1 and VT2, the more energy and aerobic potential they will possess.

The good news is that it's possible to extend one's distance between VT1 and VT2 such that a person can work at higher intensities before hitting the second ventilatory threshold. This capability can be established through an optimal mix of low and high intensity training. *But how do you determine what that mix should ideally be for a particular athlete?*

Why Metabolic Testing is Important

As mentioned above, VO_2 max, VT1 and VT2 scores are physiological measures that are a part of metabolic testing, which can be performed with the VO2 Master Analyzer.

Being aware of these values can provide a useful way of optimizing the design, intensity and effectiveness of your training sessions.

Without this insight, many athletes will spend too long training at high intensities, which results in inhibited aerobic fitness gains and more susceptibility to injury.

But, with accurate VO_2 analysis, players and their coaches can **strategically construct training regimens** that are designed to produce optimal gains in cardiovascular fitness. These training plans will specify – on an individual basis – the ideal types of training and intensities an athlete should undertake to achieve desired results. In other words, they will know exactly which training zones they need to be in at any given time.

In fact, when athletes discover how they should be ideally training, many are at first shocked by how much slower they need to run or cycle in order to stick to their optimal training zones.

With smarter training procedures, it doesn't take long to begin to see the substantial value of VO_2 analysis: more energy while competing and quicker and more effective recovery, which translates to improved overall performance.

For example, an Olympic athlete equipped with the information as to how to train more effectively than her competitors **has a distinct advantage when it comes time to compete for gold.**

Why Does the Body Need Oxygen?

We now turn our focus to exploring how the body uses oxygen. This information will be important in developing a deeper understanding of how metabolic testing can be used to guide training to use oxygen more efficiently, and thus improve our fitness levels.

Muscles Need Oxygen to Function

All cells, including muscle cells, require oxygen to function. Energy inside cells comes in the form of **adenosine triphosphate (ATP)**, a molecule that carries energy within cells. Most of our ATP is created through the breakdown of metabolic substrates (food) **using oxygen**, resulting in CO_2 and water. This means that oxygen is very important, and as you exercise, energy requirements go up – so you need more oxygen.

Oxygen is first absorbed by the blood as it passes through the lungs, binding to a special protein called **hemoglobin** contained within red blood cells. Now tied to hemoglobin, oxygen is pumped by the heart through the vascular system to the rest of the body. The oxygen is then released into the cells where it is used in the breakdown of molecules to create needed energy.

Muscles performing work require increasing amounts of energy as the workload increases, which correspondingly requires more and more oxygen.

We breathe more when we exercise to help remove the large amount of carbon dioxide (CO_2) that is produced by the working muscles. As carbon dioxide levels increase, hydrogen ions are also produced, which reduces the pH of the system, which is very tightly regulated through chemoreceptors in the brain and carotid arteries.

Figure 2.0 shows the oxygen usage for a person starting at rest, progressing to exercise at an intensity that is 75 percent of their maximum and returning to rest.

We observe that the VO_2 (oxygen uptake) increases as intensity increases and drops upon stopping the exercise.

Oxygen deficit is defined as the difference between the oxygen intake of the body during the early stages of exercise and during a similar duration in a steady state of exercise.

EPOC is an abbreviation for **excess post-exercise oxygen consumption** (also known as **oxygen debt**) and refers to the amount of oxygen required to restore your body to its normal, resting level of metabolic function.

To understand this effect, think about how you breathe heavy for a while after you have finished a hard run.

However, it is important to note that the heavier breathing required by the body in the EPOC stage **is not delivering more oxygen** – but instead eliminating excess carbon dioxide in order to maintain a healthy pH balance.

Anaerobic Metabolism

Muscles can produce energy without oxygen in a process called anaerobic metabolism. The only fuel that can be burned anaerobically is carbohydrate, being converted into a substance called pyruvate through glycolysis and then into **blood lactate** via anaerobic metabolism.

It is a common misinterpretation that blood lactate has a direct negative effect on muscle performance. Lactate is, in fact, a buffer to the hydrogen ions produced during glycolysis. While increasing lactate does correspond to an observed drop in pH level, lactate does not contribute to the loss of muscle function. Moreover, lactate is a potent fuel for further energy production, and a necessary step in the process of refueling the liver of glycogen stores following exercise.

One other comment about anaerobic metabolism: although this form of metabolism kicks in at higher intensities leading to energy being created without the need for oxygen (burning carbohydrate instead), there are still numerous processes going on in the body that cause a continued increase in demand for and use of oxygen. In other words, regardless of the fuel source, **at higher training intensities your body requires an ever more amount of oxygen**, with a ceiling equal to VO_2 max.

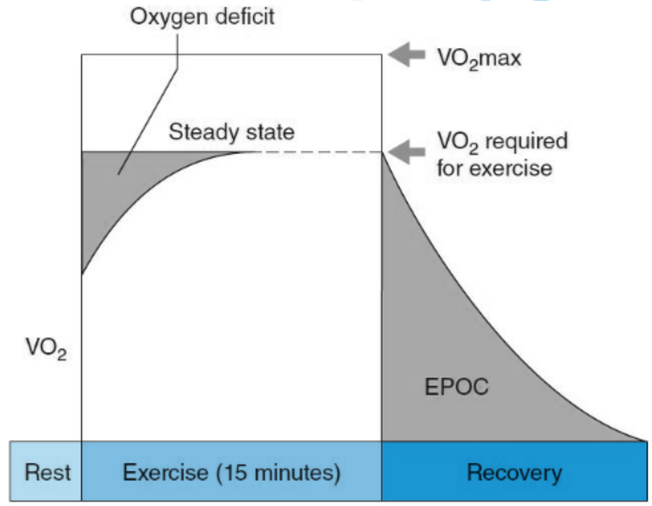


FIGURE 2.0 *Low-intensity, steady-state exercise metabolism: 75% of maximal oxygen uptake VO_2*

The Bottom Line

Clearly, fuel source is an important factor relating to the amount of oxygen consumed. At higher intensities of exercise, muscles burn mainly carbs and at lower intensities, they burn more fat. Burning fat uses more oxygen than burning carbs, but we have more energy stored as fat, so you can keep going for longer when burning without running out of energy.

Oxygen and VO_2

As you'll recall from our previous article VO_2 is simply an abbreviation for oxygen consumption – it's the measure of the volume of oxygen that is used by your body to convert the energy from the food you eat into ATP that your body uses at the cellular level.

Your VO_2 max is your maximal oxygen consumption, which is simply the maximum possible VO_2 that a given person can achieve.

Improving Your VO_2 max

Not Necessarily the Be-All End-All First, it's important to preface this section by noting that a high VO_2 max is one of numerous factors that may improve an athlete's performance; alone – and depending on the person – it may not be the most important metric to go by. Generally, a comprehensive metabolic analysis, in which a multitude of parameters are identified, is required to determine an optimal training platform for each individual.

It's Still Important

Having stated the above, it is fair to say that, in general, a higher VO_2 max – the ability to use a greater amount of oxygen – is certainly correlated with improved performance across athletic endeavors. As such, it is of benefit to understand how to increase one's VO_2 max.

Two major factors contribute to a high VO_2 max: the amount of oxygen you can transport and your muscle physiology.

Optimal oxygen transportation includes a strong heart pumping blood through the body, with hemoglobin-dense blood, a high blood volume and high capillary density in the muscles. Better oxygen transport leads to higher VO_2 max.

Muscle physiology means how many muscle fibers you have, how big they are, how many mitochondria they contain, and how strongly you can activate them during exercise. More aerobic, oxygen-guzzling muscles equals a higher VO_2 max.

Training programs can be implemented to improve VO_2 max and help increase physical fitness, improving

the way your body utilizes oxygen. These programs are designed on an individual basis and based on specific metabolic measurement values such as one's current VO_2 max, VT1 and VT2 scores. Limiting factors like genetic makeup and age all have an impact on the body's ability to increase its VO_2 efficiency – but the right training can make a big difference.

Measuring Maximal Oxygen Consumption

Let's examine how to accurately measure maximal oxygen consumption, as well as discuss some of the implications associated with different testing protocols.

Maximal oxygen consumption (VO_2 max) describes the body's ability to uptake and utilize oxygen during intense or maximal full-body exercise. It is formally defined as the maximum integrated capacity of the pulmonary, cardiovascular and muscular systems to uptake, transport and utilize O_2 , respectively.

Historically, VO_2 max has been measured by completing an incremental exercise test on a treadmill or cycle ergometer; however, it can now be measured in any training environment with the VO2 Master Analyzer. The VO_2 max test has become a cornerstone in clinical and applied physiology involving physical exercise.

Considerations for Measuring VO_2 max

There are dozens of different protocols and means of measuring VO_2 max across a number of different sports, and there are significant considerations that must be taken into account before completing a test.

1. Protocol Selection

Selecting a measurement protocol depends on such factors as fitness level of the test subject, their preferred sport, and access to appropriate equipment. Novel procedures for testing VO_2 max have been established for children, adults of varying fitness, obese individuals, and medical patient populations.

It is important to understand the relationship between an athlete's background and their measured VO_2 max. For instance, consider three athletes: a runner, a cyclist and a kayaker – all of whom are world class in their respective discipline.

Now, if we have each athlete complete incremental (graded) exercise tests to exhaustion in each of the three different sports, we will observe some interesting results. The kayaker will have a very low VO_2 max when running and cycling simply because he never uses his legs in training, but his VO_2 max will be world class when tested in a kayak. Similarly, the runner will have a high value when running and cycling and a low VO_2 max when tested in a kayak. This result has been verified by independent studies, and it is concluded that sport specificity is a critical factor when measuring VO_2 max.

This is a significant benefit of the VO_2 Master Analyzer, which permits athletes to measure their VO_2 max in their respective sport, instead of being forced to test only on a treadmill or cycle ergometer.

Graded Exercise Testing (GXT) is the most widely used assessment to examine the dynamic relationship between exercise and integrated physiological systems. Graded Exercise Testing protocols used for testing VO_2 max are maximal exercise tests where the athlete works to complete exhaustion as speed, power, or incline are increased.

Two common GXT protocols used for many individuals are the **Bruce Protocol** and the **Astrand Protcol**. These are both widely used in a clinical environment, have been extensively validated, and possess a wide range of applications for people who are able to tolerate exercise testing on a treadmill.

The differences between the two relate to speed and grade, as identified in Table 1.0.

TABLE 1.0

Bruce Treadmill Protocol Each stage is 3 minutes in duration.			Astrand Treadmill Protocol Each stage is 2 minutes in duration.		
Stage	Speed (mph)	Grade (%)	Stage	Speed (mph)	Grade (%)
1	1.7	10	1	5	0
2	2.5	12	2	5	2.5
3	3.4	14	3	5	5
4	4.2	16	4	5	7.5
5	5.0	18	5	5	10
6	5.5	20	6	5	12.5
7	6.0	22	7	5	15
			8	5	17.5

There are in fact many different incremental protocols that may be used to best fit a specific type of test subject. For instance, the perfect test for a 25-year-old Olympic runner will require a different set-up 60-year-old sedentary individual.

2. Length of The Test

The length of the test is also something to be considered; if it's set up to be too difficult or too easy for a test subject then it will not produce sought after data.

For example, if a test starts at or beyond a person's maximum speed, the individual will fail and not reach VO_2 max; conversely, if a test is too easy, then the subject may eventually tire due to an unnecessary duration of the test itself, and may not reach their true VO_2 max.

Broadly speaking, a VO_2 max protocol should ideally fall between 8-12 minutes in duration; however, there are several new protocols that have been developed which now challenge this long held theory.

Please note: Because GXTs are maximal exercise tolerance tests, they require a physician's clearance and expert supervision. In an untrained individual or an athlete with an underlying heart condition, exercising to a maximal effort can lead to injury or cardiac event.

3. Future Considerations of Exercise Testing

The information from Graded Exercise Tests can be applied across the spectrum of sport performance, occupational safety screening, research, and clinical diagnostics. The suitability of GXT to determine a valid maximal oxygen consumption (VO_2 max) has been under investigation for decades. Although a set of recommended criteria exists to verify attainment of VO_2 max, the methods that originally established these criteria have been scrutinized (M. Beltz et al; 2016). Many studies do not apply identical criteria or fail to consider individual variability in physiological responses.

As an alternative to using traditional criteria, recent research efforts have been directed toward using a supramaximal verification protocol performed after a GXT to confirm attainment of VO_2 max. Furthermore, the emergence of self-paced protocols has provided a simple, yet reliable approach to designing and administering GXT. Ongoing research continues to examine the utility of self-paced protocols used in conjunction with verification protocols to elicit and confirm attainment of VO_2 max. Our recommendation is that testing of subjects takes into account all of the above information to help direct you to the most appropriate test for the clients you are working with.

Determining VO_2 max

Visualizing how the body is responding to increasing exercise intensity/load is always a good first check for a VO_2 max test. You should see that heart rate and oxygen consumption will increase throughout the test. At the end of the test, you may observe that both heartrate and VO_2 max begin to level out. When using the VO2 Master Analyzer, the test subject's VO_2 max will be determined and displayed via the VO2 Master Manager app, so no additional manual determination is required. This feature can be adjusted based on the protocol design within the app itself.

How to Train Based on Metabolic Test Values

As we have identified, a myriad of data is determined when conducting metabolic testing, such as VO_2 max, respiratory frequencies and tidal volumes. We look to any changes in these measurements (from previous tests) to determine if training is in fact positively affecting the results.

You'll recall that your VO_2 max (measured in ml/kg/min) is the maximum amount of oxygen you can utilize during exercise, but for all intents and purposes, it's a marker of just how fit you actually are.

Your VO_2 max value is an indication of your endurance performance potential, and it can be used to help monitor your training routine over time. It's advised to conduct metabolic testing before you begin a training program and periodically to retest to identify whether the training is having the positive effect you are expecting.

What's a good VO_2 max score? Simply put, it varies by individual and their activity of choice. A sprinter, for example, will possess a lower VO_2 max score than a long-distance runner, but that may not make them any less of an athlete. For your reference, here are some general measures of typical VO_2 max scores for men and women by age category, based on cumulative data collected from thousands of athletes.

TABLE 2.0
Normative Data For VO_2 Max

Female (values in ml/kg/min)						
Age	**Very Poor**	**Poor**	**Fair**	**Good**	**Excellent**	**Superior**
13-19	<25.0	25.0-30.9	31.0-34.9	35.0-38.9	39.0-41.9	>41.9
20-29	<23.6	23.6-28.9	29.0-32.9	33.0-36.9	37.0-41.0	>41.0
30-39	<22.8	22.8-26.9	27.0-31.4	31.5-35.6	35.7-40.0	>40.0
40-49	<21.0	21.0-24.4	24.5-28.9	29.0-32.8	32.9-36.9	>36.9
50-59	<20.2	20.2-22.7	22.8-26.9	27.0-31.4	31.5-35.7	>35.7
60+	<17.5	17.5-20.1	20.2-24.4	24.5-30.2	30.3-31.4	>31.4
Male (values in ml/kg/min)						
Age	**Very Poor**	**Poor**	**Fair**	**Good**	**Excellent**	**Superior**
13-19	<35.0	35.0-38.3	38.4-45.1	45.2-50.9	51.0-55.9	>55.9
20-29	<33.0	33.0-36.4	36.5-42.4	42.5-46.4	46.5-52.4	>52.4
30-39	<31.5	31.5-35.4	35.5-40.9	41.0-44.9	45.0-49.4	>49.4
40-49	<30.2	30.2-33.5	33.6-38.9	39.0-43.7	43.8-48.0	>48.0
50-59	<26.1	26.1-30.9	31.0-35.7	35.8-40.9	41.0-45.3	>45.3
60+	<20.5	20.5-26.0	26.1-32.2	32.3-36.4	35.5-44.2	>44.2

Table Reference: The Physical Fitness Specialist Certification Manual, The Cooper Institute for Aerobics Research, Dallas, TX (1998)

Why VO_2 max Varies for Women

The trend of lower of VO_2 max scores in women is a result of size, muscle mass, oxygen carrying capacity and lower total blood volume.

Information is Power

Your VO_2 max score and additional metabolic test values, such as your Ventilatory Thresholds, permit you to craft a personalized training plan for whatever goal you have – improving cycling endurance, mobilizing fat stores, but mostly, becoming the fittest and most efficient athlete you're capable of being.

Using your metabolic data to guide training will help ensure that you're training productively. Continued regular testing will help ensure that whatever training program you're on is having the effects you want. If the training is working, then great – you should continue with it. If the training isn't working, then consider modifying your program, and try a different approach.

It is recommended that you pursue a training plan for a number of weeks before retesting, and then make a decision based on updated metabolic data.

How to Craft a Training Plan Based Off Your Metabolic Data

If you own or have access to a **VO2 Master Analyzer**, you can use it to measure your VO_2 max and other metabolic factors at any time. If not, then you'll need to meet up with a person or facility that carries a metabolic tester, which may be your coach, your physiotherapist, or a friend. Metabolic testing has become more accessible in recent years due to the affordability and popularity of the VO2 Master Analyzer.

Another great thing about the VO2 Master Analyzer is that its portability permits you to test while exercising in your sport of choice. For example, using a skatemill if you're a hockey player, outdoors on a bicycle for cyclists, or on roller skis for cross-country skiers.

Without determining your personalized numbers, you're essentially running blind and simply guessing as to which type of training is working.

When you complete your VO2 Master Analyzer metabolic test, look to see where your limitations are. For example, this may be your volume of breathing (tidal volume). In this case, if a person can't take a big enough

breath, then they will need to breathe faster to eliminate their CO_2 build up. Breathing faster is inefficient and wastes energy – energy that could instead be applied to running faster.

You may see your VO_2 max as a limitation, in which case you need to identify which part of the VO_2 max contribution is causing the issue. The contribution to VO_2 max is affected by numerous factors, such as the size of your heart, how fast it can beat, the carrying capacity of oxygen in your blood, or your muscles' ability to extract oxygen. The VO_2 max number itself will give you an indication of your fitness ability; however, determining the exact factor is a complicated discussion and one that we will delve into in our Advanced Series.

If your metabolic assessment identifies a limitation in aerobic fitness, your training regimen should be focused on low-intensity, steady state exercise. To improve your performance, it's advised that you train at this heartrate for 60 minutes, four to six times a week, and as often as you're able to fit it into your schedule and recover from the sessions.

After 6-8 weeks, retesting will allow you to determine which beneficial effects have taken place. If improvement is being seen, then the training program should not be changed. If positive effects are not seen, then consideration should be given to modifying the plan.

Retesting your metabolic data regularly is very important in order to gauge progress. It should be recognized that factors affecting and limiting a person's fitness are extremely individual in nature. This is the problem with providing a universal plan or recipe that is meant to be applicable for a group of athletes. For example, two people with the same VO_2 max scores may have different limitations one may have a respiratory limitation (e.g., exercise-induced asthma) while the other may have an oxygen delivery limitation (e.g., low iron leading to low total hemoglobin, which turn leads to low oxygen carrying capacity). Therefore, the specifics of their respective training programs should be different to effectively address each of their limitations (this will be covered in an advanced series article in the future).

That said, here is a program that is likely to assist in the general case of improving one's VO_2 max.

The VO_2 max Training Plan

The training program below is very uncomfortable. Keep it up for 6 weeks and most people should have a 10 percent higher VO_2 max stat to brag about.

Please note, after completing this program for 6 weeks, retesting is recommended at any time that a change is noticed and a shift a training intensity may be required. There is a real risk for burnout and decreased performance if intensities are too high or if the intervals are too long and this is why consistent testing is so important.

Directions: Complete 60 minutes or more of low-intensity endurance work for 3 to 4 times a week. Then try adding in the following workout **once per week** for 6 weeks and retest weekly, if possible, or at the end of the 6-week period to watch for the changes that you expect to see.

Workout 1 *45 minutes total*

Complete on a bicycle, treadmill, track or using other suitable training equipment.

- Perform 3 rounds of 30 seconds of maximal intensity effort, followed by 2 1/2 minutes of rest.
- That's one set.
- Rest for 6 minutes after each set.
- Repeat the set 3 times.
- Complete once per week for 6 weeks.

If this workout is benefitting you but getting easy then increase the number of reps/sets to make it more challenging.

After 6 weeks, if positive changes are happening, then continue with this plan, because it's working. If you see a plateau in performance or no change is occurring, then you can try one of these alternate workouts.

Alternate Workout 2

Complete on a bicycle, treadmill, track or using other suitable training equipment.

• Perform 3 rounds of 90 seconds of maximal intensity effort, followed by 2 minutes of rest.

• That's one set.

• For the first two weeks, stick to one set.

• For weeks 3-6, complete 2 sets with 6 minutes of rest between the two.

Alternate Workout 3

Complete on a bicycle, treadmill, track or using other suitable training equipment or via jump squats.

• Perform 6 rounds of 10 seconds of maximal intensity effort, followed by 3 minutes of rest.

• That's one set.

• For the first two weeks, stick to one set.

• For weeks 3-6, complete 2 sets with 8 minutes of rest between the two.

In reality, VO_2 max is one measure of fitness potential rather than fitness itself. This means that knowing your VO_2 max and other metabolic information is a useful place to start any training plan. You should be encouraged and expect changes over time in measurements of parameters VO_2 max, Ventilatory Thresholds or personal records over a particular distance. VO_2 max is a useful metric, but it is only one number in a myriad of values that VO2 Master Analyzer can provide.

Determinants of Team Sports Performance

Lastly, we turn our attention to identifying and discussing metabolic factors that affect athletic performance in team sports.

Athletic Capacities

Without question, physical capacity of athletes is an important element of success in every team sport. This involves a massive number of different physiologic parameters, with aerobic capacity playing a significant role.

Maximal oxygen uptake (VO_2 max) has been regarded by a majority of researchers as the best indicator of aerobic capacity. This single measurement indicates the functional capacities of

the cardiovascular and respiratory systems, as well as the capacity of tissues to utilize oxygen.

Metabolic Testing for Teams

Measurement of the physical capacity of members of a sports team is one of the most important tasks in assessing the team's current performance. Through regular assessments, we can more efficiently guide the training process. It is now possible to directly measure maximum oxygen uptake in an athlete's sport of choice by using the portable VO2 Master Analyzer. This device eliminates the need to test everyone in a lab environment with expensive equipment.

Metabolic Determinants Study: Athletes in Team Sports

In a 2010 study 1 , researchers demonstrated the physiologic differences between two team sports, and compared these capacities to inactive subjects.

Material and Methods

The investigation included the determination of absolute and relative VO_2 max for a total of 66 male test subjects. The study was undertaken at the University of Pristina in Leposavić. The test subjects were divided into two groups of active athletes of different profiles, while the third group of athletes served as control group.

- Semi-professional soccer players (n=22)
- Semi-professional volleyball players (n=18)
- Non-athletes (n=26)

VO_2 max for all participants was determined by performing the Astrand 6-minute cycle test. Absolute values were expressed in ml/min and in relation to body weight in ml/kg/min.

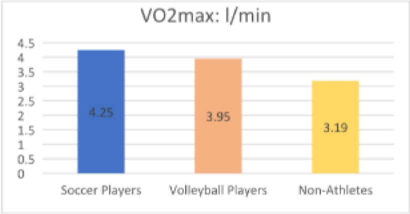
Results

Table 2.1 and Figure 3.0 display peak values of VO_2 max. The higher VO_2 max scores seen among soccer players were statistically significant. In addition, there was also a statistically significant difference between athletes and non-athletes.

TABLE 2.1
Mean VO_2 Max Values (liters/minute)

Test Group	VO_2 Max (l/min)	SD
Soccer Players	4.25	0.27
Volleyball Players	3.95	0.18
Non-Athletes	3.19	0.21

FIGURE 3.0
Mean VO_2 Max Values (liters/minute)

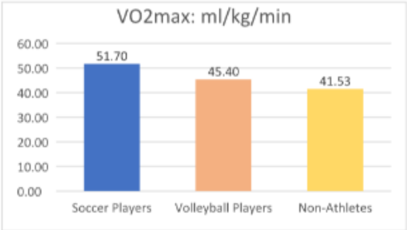


As displayed in Table 2.2 and Figure 3.1, a similar ratio of VO_2 max values was also recorded after the analysis of values expressed in relative units. The best results were obtained again by soccer players with statistically significant differences when compared to the group of volleyball players. This difference underscores the importance of aerobic capacity for elite soccer players.

TABLE 2.2
Mean VO_2 Max Values (ml/kg/min)

Test Group	VO_2 Max (ml/kg/min)	SD
Soccer Players	4.25	0.27
Volleyball Players	3.95	0.18
Non-Athletes	3.19	0.21

FIGURE 3.1
Mean VO_2 Max Values (ml/kg/min)



Discussion

The level of competition now present among elite team sports requires an extraordinary aerobic capacity for each athlete on the field. Aerobic capacity is an integral indicator of the functional capacities of all an athlete's physical systems involved in supplying, transporting and energizing oxygen transformation. Functional impairment of any link in the physiologic chain can decrease an athlete's physical capacity.

Insufficient aerobic capacity precludes the maintenance of a high level of aerobic exercise. Sports performance will be negatively affected by this fatigue, especially towards the end of a match. A high level of aerobic capacity is indispensable for achieving success in all team sports. Therefore, the determination of VO_2 max is of special importance.

The sport of high-level soccer requires sustained performance that intertwines aerobic and anaerobic exercises. The player is thus required to have an efficient system that will support their performance throughout all 90 minutes of the match.

It can be noted that there are statistically significant differences between the volleyball and soccer players. This indicates that the training associated with each sport has led to physiologic changes among the athletes.

The data related to the physiological profile of semi-professional soccer players, show that the average distance made during a match is 8-12 km, with an aerobic/anaerobic ratio of 90%:10%. In another study conducted by Diaz et al 2 , measuring the maximal oxygen uptake of Mexican professional soccer players, obtained the value of 53.8 ml/kg/min.

Furthermore, Wilmore et al 3 investigated two teams from the Norweigan Professional league, and obtained the value of 60 ml/ kg/min. The investigations of Cajasus 4 have shown that the value of VO_2 max reached 66.4 ml/kg/min in soccer players of the Spanish First League.

The takeaway here is that as we progress to higher performing soccer leagues (from the Mexican league to the Norwegian league to the Spanish league), there was an associated increase in higher VO_2 max scores.

This assertion is confirmed when we look at another study. It was also determined that soccer players of the Union of Serbia and Montenegro's First League had higher VO_2 max values (53.8 vs. 44.8 ml/kg/min) compared to amateur football players.

Conclusion

An investigation into the maximal oxygen uptake provides relevant insight into the health of players of team sports. This can also be used in providing training recommendations and the follow up to gauge an athlete's response to training. For these reasons, the increase in VO_2 max values as indicators of physical capability of team sport athletes is indispensable for achieving top sports results.

QUESTIONS? CONTACT VO2 MASTER FOR MORE INFORMATION.

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