The Winning Mindset

Scott Christensen

Understanding VO2 $_{max}$: Part 2 of 3

Purpose:

The purpose of CTCs *The Winning Mindset* is to collect and present articles by accomplished athletes, coaches, and business leaders in an effort to provide our readers with valuable insight into successful training, racing, business, and the characteristics of a high-performance mindset.

Subject:

Coach Christensen was asked to prepare a series on understanding **VO2 $_{max}$** and how to train and improve it. The first article, available on our website, is Scott providing a historical summary of the topic and introducing how VO2 $_{max}$ development applies to runners.

The second article in the series, presented here, addresses the need for energy while running and how all standard track events and cross country races are combined zone activities (requiring energy from different physiological processes).

Scott then outlines a handful of testing methods to measure one's VO2 $_{max}$ and provides three more training examples of how to apply training that improves one's VO2 $_{max}$.

The second article in this series will expand the discussion by explaining multiple ways to test for one's VO2 $_{max}$. Scott then provides more training examples that demonstrate how to specifically target aerobic power development.

Scott Christensen has produced volumes of excellent training presentations that are available for purchase at **CompleteTrackandField.com**.

Coach Christensen's Response:

All of the standard distance races including cross country running are *combined zone* races. Combined zone means that the ATP energy molecules needed for muscular contractions at race pace are resynthesized from both aerobic and anaerobic reactions in combination with each other. Improvement in both the capacity and efficiency of these energy deriving reactions and how well they work in combination is the main focus of endurance training.

Anaerobic energy delivery is improved through maximum, or near maximum velocity stimuli. Gains in the system are made through neural improvement at the neuromuscular junction, improved neuro-muscular biomechanics during maximum effort, myosin (muscle fibrils) cross-sectional size increases, and muscle cell adaptations that allow for greater drainage and tolerance of lactate and hydrogen ions. The energy contribution of anaerobic reactions varies from 50% in the 800 meters to about 8% in the 5000 meters. The training emphasis of the anaerobic energy division is dictated by the selected race distance of the athlete.

Aerobically derived ATP molecules contribute more than 50% of the energy needed to run a distance race at maximum race pace. The characteristics and duration of the race distance will dictate the amount of aerobic training emphasis for the athlete. For an endurance coach, the most important knowledge possessed regarding aerobic energetics and training is found in the physiological concepts of aerobic power and aerobic capacity.

Aerobic reactions on their own cannot deliver enough ATP energy to meet distance race pace, even if these reactions are operating at maximum levels. As the velocity of the race intensifies, so must the biochemical reactions in muscle cells that facilitate movement. Because aerobic reactions in muscle cells involve two large-scale cyclic processes (glycolysis *and* the Citric acid cycle), ATP production is viewed as efficient but slow. Aerobic ATP production alone is adequate for sitting, walking, and even jogging, but eventually, race pace gets fast enough that aerobic energetics cannot keep up with the ATP production that is needed. In essence, the aerobic system is "maxed" out, and no more oxygen can get to, or be utilized by the mitochondria in muscle cells (figure 1). In order to go faster (greater intensity) a runner will need supplemental anaerobically produced ATP molecules to produce quicker movements.

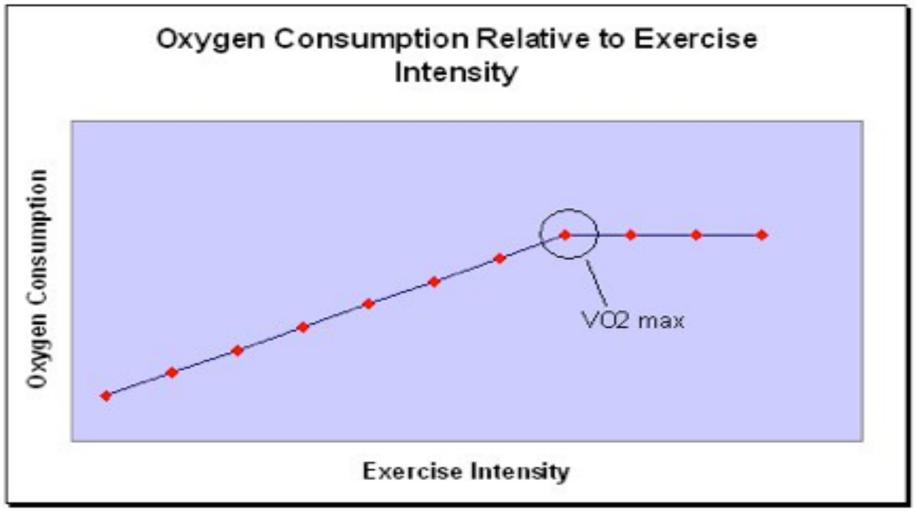

Figure 1. The oxygen consumption inflection point $VO_{2\,max}$ is intensity dependent.

The oxygen maxed-out point in the aerobic system is not permanently fixed in individuals and can improve with training. Physiologists and coaches call this $VO_{2\,max}$ training. The goal of this type of training is to improve to a faster running velocity (intensity) but at the same level of oxygen consumption. In correlation with maximum oxygen consumption velocity improvement, theoretically, there should be an improvement in sub-maximum oxygen consumption ($VO_{2\,sub\text{-}max}$) velocity as well.

There is only one track event where the race intensity is within 99-101% of the $VO_{2\,max}$ inflection point shown in figure 1, and that is 3000 meters (at sea-level) for most people. All other standard race distances are either $VO_{2\,sub\text{-}max}$ intensity, shown as percentages less than $VO_{2\,max}$, or races higher than $VO_{2\,max}$ intensity, shown as percentages greater than $VO_{2\,max}$ (table 1). The higher percentage races will need quite an anaerobic energy contribution to achieve race pace since the aerobic system is all maxed out at 100%. Table 1 is crucial for understanding what to train for regarding specificity of the various distance events. Those distance events within 5% of $VO_{2\,max}$ intensity (up or down) should have a very high emphasis on training units designed to directly improve $VO_{2\,max}$ itself, or what is called aerobic power. Events further away in percentage (up or down) should mark $VO_{2\,max}$ as important training sessions, but done in conjunction with other work to improve aerobic capacity (as in the 10,000 meters) or lactate tolerance (as in the 800 meters).

Race Event Distance	$\%VO_{2\,max}$
800 meters	120-136%
1600/1500 meters	110-114%
2000 meters	105-106%
3200/3000 meters	99-101%
5000 meters	97%
6000 meters	96%
10000 meters	92%

Table 1. The fractional percentage of $VO_{2\ max}$ utilized for various race distances.

Since running 3000 meters to exhaustion is considered a person's $VO_{2\ max}$ limit, then 3000 meter race pace should be the velocity that is required to achieve $VO_{2\ max}$ for an individual. It is, and that pace is called $vVO_{2\ max}$ (v is velocity). Once that number is known, it should be possible to determine performance goals for all of the related distance events based on table 1.

Let's look at an example. Brooke recently ran a 3200 meter race on the track in 12:40, at 1325 feet above sea level, on a 59F day with little to no wind. Brooke's honest $vVO_{2\ max}$ is 6:20/mile. What can she run the 1600 meters in? Referring to table 1, 110% of 6:20 is 5:45, which should be Brooke's current 1600 meter effort on a similar day. How about the 5000 meters? 97% of 6:20 is 6:31/mile, so for 5k it is 3.1 times 6:31, or 20:21 if run on a track. If Brooke is looking for a cross country time she will have to adjust that 20:21 for grass (maybe add 45 seconds). All the different events can be done in a similar way to get specific race times for a known $vVO_{2\ max}$ time. A coach can also mathematically work backward using table 1 percentages to determine $vVO_{2\ max}$ from a current performance in one of the other events listed.

If using 3200 meter race performances or time trials to determine $vVO_{2\ max}$ it is important that the data be kept current. Every 21 days a new $vVO_{2\ max}$ "date pace" needs to be established in order to keep table 1 relevant, and to determine appropriately paced aerobic work sessions.

Per-Olaf Astrand, the well-known Scandinavian exercise physiologist proposed the 3200 meter race performance, or 2 mile time trial to determine an individual's $vVO_{2\ max}$. However, it is not always easy or convenient to determine a runners $vVO_{2\ max}$ with a 3200 meter effort. Athlete field tests for $vVO_{2\ max}$ can be determined in a number of acceptable ways based on the age and fitness of the athlete and they include: a.) a five minute test to exhaustion, b.) a ten minute test to exhaustion, c.) a one mile to exhaustion, d.) a two mile to exhaustion, or e.) 65% of an exhaustive 400 meter time. Since, $vVO_{2\ max}$ is a measure of aerobic fitness, recall that it takes 2-3 minutes for the aerobic processes to reach full capacity in the mitochondria of the cell. Basically, the test needs to be at least five minutes in duration for most applications to satisfy this window of time. The issue with tests a and b is that the trial results (each day they are done) are measured in distance and not time. A coach will need a very accurate method to measure the distance covered in the prescribed time period, and then do additional math to get $vVO_{2\ max}$ to a useable value. Test c is a good test for determining athletes accurate $vVO_{2\ max}$ at terrestrial altitudes above 5000 feet. Recall that sea-level $VO_{2\ max}$ values are accurate for most runners below 5000 feet (1500 meters), but for every 5000 feet (1500 meters) above that, $VO_{2\ max}$ decreases by 3-8% (it decreases by a much higher rate above 15,000 feet). With altitude effects in mind, for a runner training at 6000 feet above sea level, a one mile test done at that altitude is pretty close to $vVO_{2\ max}$ done at sea-level. Test e is appropriate for masters runners and for sprinters moving up into the endurance events who would find any exhaustive test five minutes or longer to be much too far. A 400 meter race has an aerobic energy supply component of 38%, which is too small for the event to be considered a distance event, but large enough to use as an initial $vVO_{2\ max}$ data point (after dividing by .65) until the runner gets aerobically fit enough to handle the longer tests. By far, the most accurate $VO_{2\ max}$ and $vVO_{2\ max}$ tests for distance runners are the ones done a treadmill in a physiology laboratory. For elite runners, a treadmill test 3-4 times a year would be very useful in gathering the most accurate data sets possible. For the rest of the distance running community, coach administered field tests that are updated every 21 days will work very well.

Training pace is the key to effective $vVO_{2\ max}$ based workouts. As examples, let's look at a trio of emerging runners and some different workouts they might do to stimulate the development of aerobic power in both the central and peripheral components.

1. Kara is a junior on the high school cross country team. Her training age is two and she is emerging as a varsity runner. Because the high school race distance is 5k, it competes very close to runners' $VO_{2\ max}$. What are two typical workouts her coach might do during each training microcycle to continue to improve aerobic power? Two days ago, Kara ran 11:40 for a two mile time trial. Her $vVO_{2\ max}$ is 5:50/mile. Today, Kara's coach wants her to work on central $VO_{2\ max}$ development. Kara is running about 48 miles per week during training right now. Her long run needs to be about 20% of that total in one continuous effort to optimize central $VO_{2\ max}$ development. Kara has a cross country race in two days so she does not want to do a workout today that hinders her chances in that competition. By prescribing a long run pace at 65% of her $vVO_{2\ max}$ she should be right at her aerobic threshold. By running at that pace, she gets all the stimuli of central $VO_{2\ max}$ development but spares much of her glycogen stores for the upcoming race. Most of Kara's fuel for the long run will be from free fatty acids metabolized from adipocytes (fat cells). Kara's workout today is 10 miles at 8:58/mile pace. She will need to wear a watch and have a marked 10 mile course to hit the pace she needs. This workout has a 24 hour metabolic and 48 hour neural recovery period. It will not hinder her race performance. Later in the microcycle, Kara needs to do a training session to stimulate further development of her peripheral $VO_{2\ max}$ system. Her coach is prescribing 8 x 800 meters on an asphalt trail by the lake. Recalling her recent two mile time trial of 11:40 that determined her current $vVO_{2\ max}$ of 5:50/mile, Kara will try to do the 800 meter repeats right at that pace. Recovery time to work time will be 1:1. For this workout, Kara will do 8 x 800 meters in 2:55 with 3 minutes recovery. With that specific work to recovery ratio, and at that pace, Kara should be able to hit all eight repeats in 2:55.
2. Charlie is a college junior with a training age of five. He runs cross country in the fall and is mainly a 5k and 3k steeplechase runner in track. It is April 3, what could Charlie's coach have him do at practice today that might stimulate both central and peripheral $vVO_{2\ max}$ system development? Charlie ran 9:10 for a two mile time trial a couple of days ago, so his $vVO_{2\ max}$ is 4:35/mile. Today Charlie is going to do a continuous seven mile run at 70% of $vVO_{2\ max}$, and then after a 10 minute break for a sip of water, he is going to do 4 x 1600 meters at 100% $vVO_{2\ max}$ with a work to recovery ratio of 1:1. Charlie will try to run the seven mile continuous effort in 6:30/mile and then the 1600 repeats in 4:35/mile with a recovery interval of 4:30 between repeats. There is a 48 hour recovery period from this workout.
3. Carlos is a 400 meter runner moving up to compete in the 800 meters. He is a high school senior with a training age of two. He can run a mile ok, but to run a two mile time trial is not so appealing. What can Carlos's coach prescribe to boost his aerobic power? Carlos ran 5:12 for the mile last week, so his $vVO_{2\ max}$ is about that pace because of his lack of $VO_{2\ max}$ development. Today, Carlos is going to try to run 6 x 600 meters at current $vVO_{2\ max}$, with a work to recovery ratio of 1:1.5. However, first Carlos is going to run 400 meters as hard as he can, just to tire him about a bit, and then he will recover 15

minutes before starting the 600 meter repeats. The 400 meters should be an all-out effort. The 600 meter repeats should be run in 1:57 with three minutes recovery between each repeat. There is a 48 hour recovery on this workout.

Exercise scientists have suggested that the most effective way to train to improve peripheral $VO_{2\ max}$ aerobic power is to train right at present-day $VO_{2\ max}$ velocity. Date pace 3200 meter velocity, broken into interval training sessions of 600, 800, 1000, or 1600 meter distances being the most powerful. The total workout volume should be between 5500 and 7000 meters. In most cases, recovery time should be equal to work time during the session. These types of workouts should be done once per microcycle during the entire season for events run near $VO_{2\ max}$.

For central $VO_{2\ max}$ aerobic power development, long runs, tempo runs and critical velocity work which fractionalizes $vVO_{2\ max}$ are the most powerful work sessions. For those events run near $VO_{2\ max}$, they must be done concurrently with peripheral work. However, for those events further from $VO_{2\ max}$, central development is all that is really needed, with only a few training sessions each season at 100% $vVO_{2\ max}$.