Lactate Testing Handbook

VERSION 2

HIGHNORTH

This guide is intended to provide a practical guide to performing lactate testing at home. In the interests of brevity and to keep things as simple as possible, we won't go into the science of what lactate is, or why you might want to test it. These topics are covered in our complete training guide.

Please note that this guide has been updated to incorporate new learnings from undertaking a higher volume of home-based lactate testing with our athletes over this last year. In particular, some of the protocols have been adapted to make them simpler to perform and interpret independently of a coach. Please refer to this new version over older versions of this guide.

If, after reading this guide, you are still not entirely confident performing or interpreting the results of your testing, you might wish to arrange a consultation with us. Drop us an email at info@highnorth.co.uk if this is something you'd be interested in.

In this guide, we will cover:

WHAT DO I NEED TO BEGIN?

Before you begin you will need:

- An indoor trainer with the ability to measure power (either via a power meter on your bike, or using a smart trainer).

- A lactate analyser. We recommend the Lactate Pro 2, which we find to be a good analyser for beginners, as it's easy to use, doesn't require calibration, gives fewer error readings than other devices, and can be used with very small amounts of blood.

- A set of lactate strips that are compatible with the lactate analyser (see below for approximate requirements for each test).

- A set of safety lancets. We use these 28 gauge lancets, but if you're a beginner, you might want to use some with a lower gauge (i.e. bigger diameter), which will help you get a bigger blood drop.

- Alcohol swabs.

- Some tissues.

- A timer of some sort e.g. a phone.

- A towel.

- Something you can use to record your results (e.g. pen and paper or laptop).

Optional (but recommended):

- Software that can be used to fix your power in 'erg mode' (e.g. Zwift, TrainerRoad etc.).

- Someone to help take samples.

- One pair of disposable gloves for your helper. We recommend avoiding latex gloves, as many people are allergic to these. Nitrile gloves work well.

HOW TO TAKE A LACTATE SAMPLE

Lactate samples can be taken either from your finger tip or an earlobe. If you are doing the testing by yourself, you'll need to take these from your finger.

Below is the protocol we use. By far the biggest reason you'll get incorrect lactate readings is due to contamination of the blood sample, so most of the steps are concerned with minimising contamination. These steps are important and shouldn't be skipped.

- Get prepared. Before it's time to take a sample, prepare your equipment, by opening the alcohol swab, taking the cap off the lancet (if applicable) and inserting the lactate strip into the lactate analyser. Take care not to touch either end of the lactate strip (neither the chip end that goes into the analyser, nor the testing end that absorbs the blood). This can contaminate the strip and lead to incorrect results.

- Once it's time to take the sample, use a towel to wipe away any sweat from the sampling area (i.e. finger or earlobe) and surrounding area. In you're a heavy sweater, be generous with the wiping - e.g. do the whole hand, and even the arm and face, as sweat can drip from these areas onto the testing area and contaminate the result.

- Wipe the sampling area with an alcohol swab to ensure it's clean. **Allow the finger/earlobe to dry fully before proceeding to the next step**. This is important because the alcohol can also contaminate the sample.

- Prick the finger or earlobe with a lancet and squeeze out a small drop of blood. If sampling from the finger, it's best to prick slightly to the side of the finger (rather than right in the middle of the finger pad).

- **Wipe the initial drop of blood away with a tissue**. The first drop of blood will not provide a reliable lactate reading, as it will be contaminated with tissue fluids.

- Squeeze out another drop of blood. This will ideally form a nice raised globule a few mm in diameter. If the blood starts running down your finger, wipe this away, and squeeze again to form a droplet.

- Very carefully insert the lactate strip into the blood droplet. The lactate strip should just touch the surface of the droplet, and **should NOT touch the skin** (again, this can cause contamination). You should see the blood soak up the testing strip, and the lactate analyser will probably beep to tell you it's successfully taken a sample.

- Lastly, wait for the analyser to show you your result, and take a note of this.

Extra Tips

- In the early stages of testing, blood may not be flowing too well. Try warming up your hands or shaking your arms around before taking a blood sample. This should help to increase blood flow to the fingers.

- When squeezing out a blood drop, don’t squeeze too hard. This can increase the content of tissue fluids within the blood drop and will dilute the lactate concentration.

- To stabilise the analyser and minimise the risk of the lactate strip touching the skin, your helper can rest their hand or a finger against your hand or head to steady their own hand. If you are taking lactate samples from the finger, you should also rest your own hand on the handlebars.

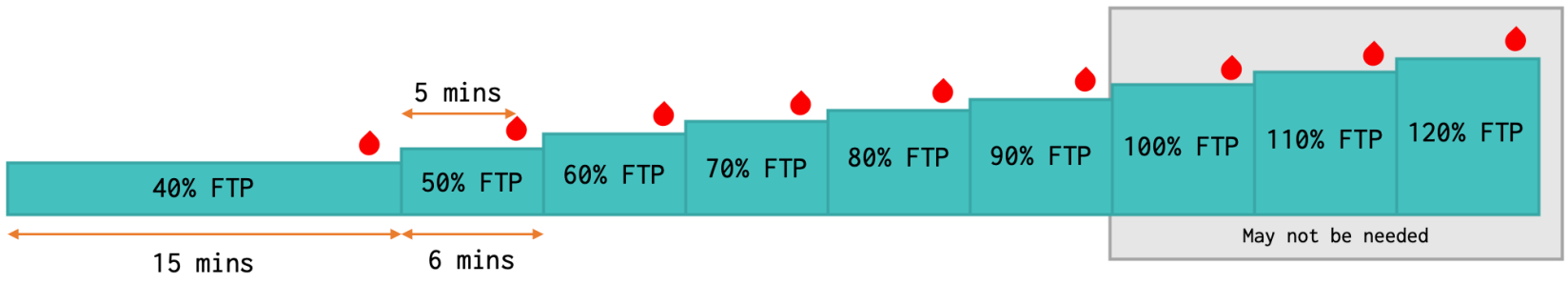
- Always be on the look-out for erroneous lactate values. If you see a big jump in lactate values between stages of the test, it’s best to take a second reading.

AEROBIC TESTS

Below are two aerobic lactate test protocols. Protocol 1 allows you to get an overall view of your lactate production rates at a range of intensities, and is useful for getting a high-level view of your physiology and how this is changing over time. However, this test cannot be used to determine your true lactate threshold power precisely.

Protocol 2 is for accurately establishing your true lactate threshold power - i.e. ‘maximal lactate steady state’ or the point beyond which lactate production exceeds clearance, and lactate levels accumulate rapidly. This can be useful if you want to precisely know your lactate threshold power for planning interval training intensities or monitoring changes.

Protocol 1: Full ramp test



Key Details

Duration	~1H plus cool-down.
No. of lactate strips required	~9-13 (more if you need to take repeat measures)
Use this test to determine…	• Overall lactate profile. • Approximate location of LT1 or aerobic threshold. • Approximate location of LT2 or lactate/anaerobic threshold.

Protocol

- Begin with a 15-minute warm-up at a very low intensity. The specific starting intensity will depend on your fitness level and estimated lactate threshold, but for most people, we recommend starting at around 40% FTP. It’s important that this intensity is low so that we don’t miss LT1 by starting too high.

- Take a lactate sample 10-14 minutes into this warm-up and record the result and associated power.

- Next the ramp test begins in earnest. Each lactate sample should be taken 5 minutes into each stage. However, we recommend making each stage 6-mins long, as this allows time for the lactate sample to be taken, and also allows for a second sample to be taken if something goes wrong with the first.

- The power increment for each ramp will depend on your fitness level and estimated lactate threshold. However, a convenient rule of thumb is to increase each stage by 10% of your estimated FTP.

- Remember to record the lactate results and the associated power as you go.

- Continue with the ramp test until you record a lactate value that exceeds 6mmol/L or if your heart rate exceeds 95% Max Heart Rate. Once either of these conditions is met, you can stop the test.

Testing Tips

- If it’s your (or your helper’s) first time taking lactate samples, take a few extra measures during the warm-up to practice.

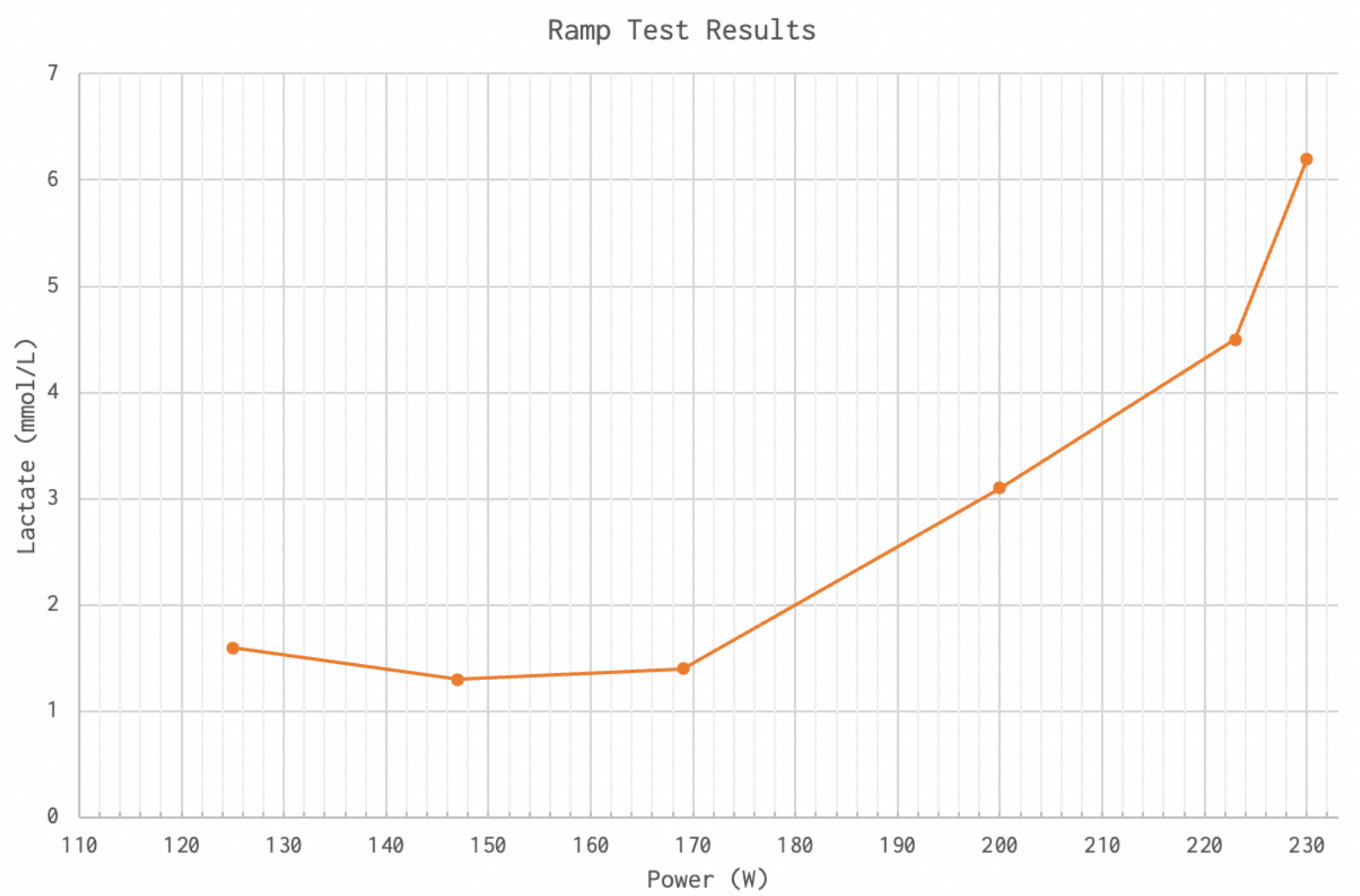
- While it’s not essential, we strongly recommend using erg mode to keep power stable. This is important, because fluctuations in power will impact your lactate readings and could invalidate the results.

- You can do the test either seated or standing, but you will need to be consistent across each stage of the test (including the warm-up), and also across repeated tests. We only recommend doing the test standing if you typically do most of your riding out of the saddle.

- If you don’t have a helper and are taking your own lactate samples, we’d recommend testing after 6-minutes rather than 5-minutes. You can then pause the ramp test at the end of each stage to take the sample. This will allow you to take the sample without having to continue riding, and having a 6-minute long stage will mean that the brief break in riding won’t impact your lactate results, as 6-mins is sufficient for your lactate levels to stabilise with each stage.

Analysing the Results

To get an overview of your lactate profile, plot the power of each stage (x-axis) against the lactate value (y-axis), as shown:



Many labs use fixed lactate values of 2mmol/L and 4mmol/L to determine LT1 and LT2 respectively. However these values are based on population averages, and often aren't accurate at an individual level. Moreover, these values are highly influenced by things like prior nutrition, fatigue, and time of day. So using fixed cut points can lead to invalid conclusions when assessing changes over time, if these factors aren't well controlled.

With this ramp test approach, we prefer to interpret the data visually to see:

(i) How high the lactate levels are overall. High lactate levels (e.g. ~2mmol/L or above) in the early stages of the test can indicate poor fat oxidation ability.

(ii) What the overall lactate curve looks like. Are there any clear inflection points that can give a rough marker of where LT1 and LT2 may sit.

In the graph above, lactate levels begin at a fairly typical level. We can see inflection points at around 169W and 223W, suggesting LT1 and LT2 may sit around

these wattages, although as noted previously the ramp test is not an accurate method for determining these thresholds.

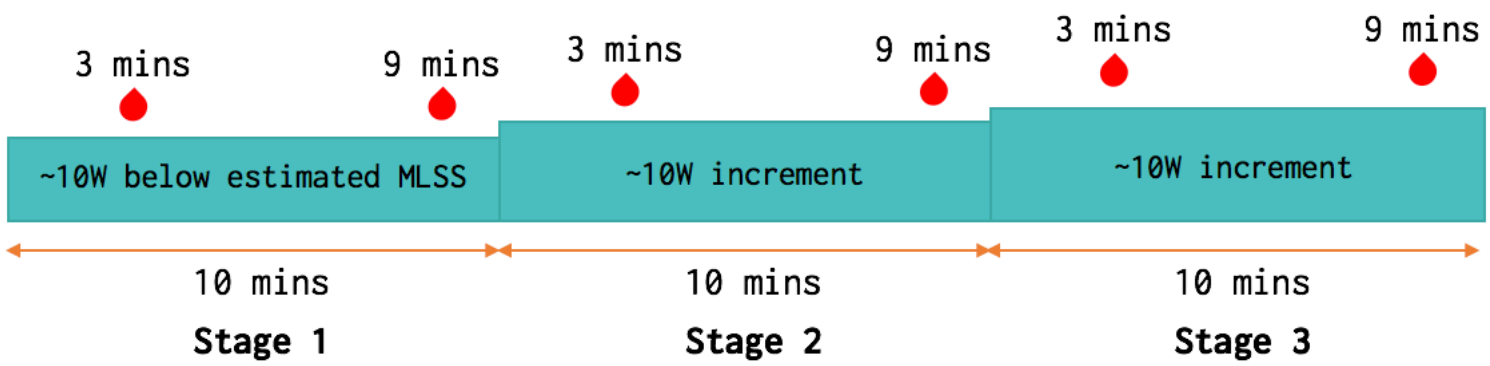
In subsequent tests, we could then assess whether the overall shape of the graph has shifted. For example is there evidence that the inflection points now occur at a higher power? Or does lactate ramp up less steeply, which might suggest better lactate clearance and/or lower lactate production rates.

Final Notes

You may have done previous lactate tests with shorter stages. However, the results of these tests are less valid, because lactate levels take time to stabilise after each step increase in power. We therefore would not recommend shortening the stages beyond what is recommended above.

Having long stages is also useful because, if you need to take a repeat test and pause the workout, the results won’t be impacted by this break in riding, as each stage has sufficient time for the lactate levels to stabilise and will not be meaningfully impacted by the starting lactate value.

Protocol 2: Maximal lactate steady state



Key Details

Duration	~40-mins or more
No. of lactate strips required	4 or more
Use this test to determine…	Maximal Lactate Steady State (MLSS)
Notes	Only recommended where precise determination of MLSS is needed.

Use Case

As mentioned, Protocol 1 is good for getting an overview of your lactate profile, but is not appropriate for determining your lactate threshold (i.e. MLSS) precisely. This second protocol is designed to establishing your MLSS with better precision.

Traditionally, MLSS is tested over several days, but we've included an adapted version of a 1-day protocol by Palmer et al. (1999).

Protocol

- For this protocol, you'll first need a good estimate of where your MLSS probably sits. You can use information from Protocol 1, alongside field-based FTP testing and your subjective sensations while riding to estimate this. In general, your MLSS will be lower than your FTP derived from any field-based test. The idea is to complete an effort below your MLSS, and then make small increments in power until you exceed your MLSS. As each effort is quite long (10-mins), we want to complete the testing in as few stages as possible, which is why we need a good estimate of MLSS before starting.

- After a 10-minute gentle warm-up, begin with Stage 1: a 10-min steady state effort at around 10W below your estimated MLSS (if you're unsure of your MLSS estimate, you might even want to begin at 15-20W lower).

- Take blood samples at 3-mins and 9-mins into Stage 1. Lactate should not have increased by more than 1mmol/L between the 3-min and 9-min measures, inducting that you're below your MLSS. If it has increased by more than 1mmol/L, you're already above your MLSS and have started too hard, and you'll need to rest for ~10 minutes and start this stage again.

- Provided lactate values increase by no more than 1mmol/L during Stage 1, progress to Stage 2.

- In Stage 2, complete another 10-min steady state effort, this time at ~10W higher than Stage 1, again taking blood samples at 3-mins and 9-mins.

- If your lactate has increased by more than 1mmol/L between the 3-min and 9-min measures this indicates that Stage 2 was above your MLSS, and that your MLSS lies between Stages 1 and 2. You can stop the test here.

- If your lactate has not increased by more than 1mmol/L this indicates that Stage 2 was below your MLSS, and you should progress to Stage 3, by completing a further 10-min stage at 10W higher, again taking lactate samples at 3-mins and 9-mins.

- If your lactate has increased by more than 1mmol/L between the 3-min and 9-min measures this indicates that Stage 3 was above your MLSS, and that your MLSS lies between Stages 2 and 3. You can stop the test here.

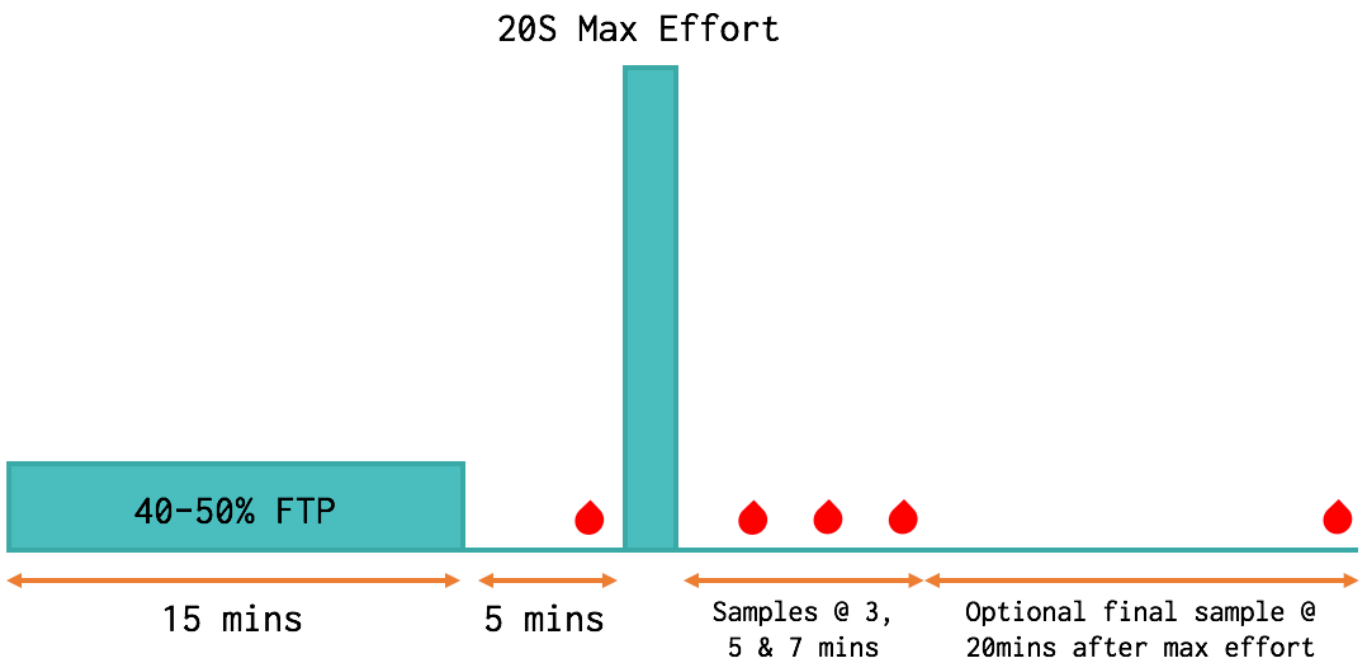
- If your lactate has not increased by more than 1mmol/L this indicates that Stage 3 was below your MLSS. If you're feeling ok, you can continue completing stages with 10W increments as described above, until you hit a stage where lactate values increase by more than 1mmol/L. Else, you can resume testing on another day, beginning at Stage 3 + 10W.

Testing Tips

- While it's not essential, we strongly recommend using erg mode to keep your power stable. This is important, because fluctuations in your power will impact your lactate readings and could invalidate the results.

- The protocol above establishes your MLSS to within 10W. If you wanted to determine your MLSS more precisely, you could use smaller power increments. However, we'd only recommend doing this after the 10W protocol above, so that you have a good idea of what power to start at. Otherwise, you may end up needing to complete too many stages before you exceed your MLSS, or missing your MLSS entirely.

VLAMAX + CLEARANCE TEST



Key Details

Duration	~30-40 mins.
No. of lactate strips required	4 or 5
Use this test to determine…	• VLaMax/maximal glycolytic rate • Lactate clearance rate
Notes	This test should follow after one of Protocol 1 or 2.

Use Case

This test is used to determine your VLaMax. We strongly recommend including this protocol alongside one of the aerobic tests above, because this will give a more well-rounded understanding of your fitness profile.

Protocol

- After completing either Protocol 1 or 2, go straight into 15-mins of easy riding at around 40-50% FTP. This will help clear the accumulated lactate from the preceding test. Alternatively you can do the VLaMax and clearance test on another day.

- After the 15-mins of easy riding, rest completely for around 5-mins, before taking a lactate sample. This should be below 2.5mmol/L. If it isn’t, rest a few more minutes before taking another sample.

- Then complete a maximal effort as hard as you can go for 20-sec. We strongly recommend doing this effort outdoors, ideally on a hill, as it can be had to do a true max effort on an indoor trainer.

- After the effort is complete, stop riding entirely. This is very important, as if you keep pedalling, this will reduce your lactate readings.

- Take samples at 3-mins, 5-mins and 7-mins, remaining at rest throughout. (For better accuracy, you can also take samples at 4-mins and 6-mins if you wish, continuing until you see lactate levels drop).

- Optionally remain at rest until 20-mins after the 20-sec effort, and take a final lactate sample. This can be used to examine your ability to clear lactate.

Testing Tips

- Pick a relatively big gear for the 20 sec effort, so that when you're up to speed, you don't spin out. You might want to experiment with gearing a day or so before the lactate testing to determine what works best for you.

Analysing the Results

The results you get from this VLaMax test might look something like this:

Time	Lactate
Baseline	2.0mmol/L
3-mins	10.8mmol/L
5-mins	13.7mmol/L
7-mins	11.1mmol/L
20-mins	4.4mmol/L

To determine your VLaMax:

- Identify the highest lactate level you reached. In the example above, that's 14.7mmol/L.

- Subtract the baseline lactate value (i.e. the lactate value you obtained before beginning the 20-sec effort). So in the example above, 13.7 - 2.0 = 11.7.

- Divide by 16S (this is the length of the 20S effort minus the initial 4-seconds of the effort, where energy will predominantly be provided via the creatine

phosphate system). This gives you a measure of your maximal lactate building rate or VLaMax. So in the example above, VLaMax = 11.7/16 = 0.7mmol/L/sec.

- Alternatively, after you have completed a few tests, you can just compare the maximum lactate value you hit to determine whether your VLaMax is increasing/ decreasing.

To determine your lactate clearance rate:

- Work out the percentage drop between your highest lactate value, and the lactate value at 20-mins. In this example, lactate dropped from 13.7mmol/L to 4.4mmol/L, which represents a 68% drop.

- You can also look at the clearance rate, which is the change in lactate (13.7-4.4 = 9.3mmol/L) divided by the length of clearance (20mins - 5mins = 15mins). Or in other words 9.3/15 = 0.6mmol/L/min.

Notes

- This test must be done after the full/abbreviated ramp test not before, otherwise you'll be waiting a long time for your lactate values to come right back down to baseline before you can begin the ramp test.

- You can do the test either seated or standing, but you will need to be consistent each time you do the test.

- Maximum attainable lactate values typically range between 15-20mmol/L with some specially trained athletes reaching 25mmol/L. However, it's also normal to see somewhat lower lactate values in this test, given the effort is very short, e.g. ~5-6mmol/L.

- Don't complete this anaerobic test if you have any health concerns that might be exacerbated by a 20-sec maximal effort, or if you have been advised by a medical professional to avoid high-intensity exercise.

A NOTE ON NUTRITION

What you eat before and/or during the test will impact your rest results. We therefore recommend that you make a note of your nutrition prior to and during the test, so that you can replicate this as closely as possible before any subsequent tests.

INTERPRETING THE RESULTS

LT1/Aerobic Threshold

Your LT1 gives an indication of your aerobic efficiency. An increase in your LT1 can suggest an improvement in (i) your ability to use fats for energy, (ii) your aerobic capacity (i.e. VO2max) and/or (iii) your lactate shuttling ability.

You can also use your LT1 value to give you an indication of the top of zone 1 in a three-zone polarised model.

LT2/Anaerobic Threshold/Lactate Threshold

Your LT2 or Maximal Lactate Steady State (MLSS) is the point at which lactate production equals your maximal rate of lactate clearance.

An increase in your LT2 can suggest an improvement in (i) your ability to use fats for energy, (ii) your aerobic capacity (i.e. VO2max) and/or (iii) your lactate shuttling ability.

You can also use your LT2 value to give you an indication of the top of zone 2 in a three-zone polarised model.

VLaMax

Your highest lactate value after the anaerobic test gives you an indication of your maximal glycolytic rate or VLaMax.

An increase in this lactate value indicates an increase in your VLaMax. This would usually (but not always) be associated with a decrease in your tendency to use fats for fuel.

If you choose to convert this lactate value directly into a VLaMax value (i.e. in terms of mmol/L/sec), you can get an idea of how strong your anaerobic power is. VLaMax typically ranges from around 0.2mmol/L/sec and 1.0mmol/L/sec (Heck et al.,

2003). For most endurance sports, you'd want this to ideally sit somewhere between 0.3mmol/L/sec and 0.5mmol/L/sec (the lower end for more steady-state disciplines, and the higher end for more punchy disciplines).

Lactate Clearance

Regular testing of lactate clearance is in it's infancy, so it's hard to give reliable data on typical lactate clearance rates. From our own testing, we've seen values between ~0.1-0.4mmol/L/min. We've seen data from other coaches that give values as high as 1mmol/L/min, but we can't speak to the accuracy of that data. Overall, we'd be pretty confident saying lactate clearance rates at rest probably range somewhere between 0.1-0.5mmol/L/min and possibly a bit higher. The majority of people we've tested have had values around the 0.3mmol/L/min mark, so that looks to be approximately the median value. We'll update this guide as we obtain more data.

The main use of clearance data at the moment is in determining how your clearance rates are changing over time, with training.

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