Lactate & Thresholds for Training **The Association Of Rowing Coaches, South Africa**

This blog contains articles of interest to rowing coaches worldwide and includes topics such as rowing technique, exercise physiology, training methodology, sport psychology, strength training, endurance training, drills, sports medicine, anatomy, nutrition, training planning, biomechanics, overtraining and recovery, periodization and many others.

From www.lactate.com

NOTE: **My notes and clarifications are in bold brown font.**

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What is the "anaerobic threshold"?

Before we define the "anaerobic threshold" (AT) it should be pointed out that there is no clear consensus on what this term means. This was and still is a controversial area. So when we define it, the reader should know that others may use a different definition. Many sports scientists would prefer to eliminate the term altogether. However, it is still commonly used by coaches, training books, the popular press and many sports scientists.

Originally some sports scientists thought that there was a point of exertion where the body started to use anaerobic energy heavily. This point corresponded to a sudden change in the patterns of oxygen consumption compared to carbon dioxide output as well as a rapid accumulation of lactate in the blood. Because it was a sudden change, like the passing from one physiological state to another, it was called a threshold. Because it was thought that the changes in metabolism at this point were 1) due to limited oxygen and 2) the start of using anaerobic energy, it was called anaerobic. Hence the term "anaerobic threshold" was used. It was an unfortunate choice of terms since it probably has led a lot of sports scientists, researchers and coaches down the wrong path.

"Anaerobic" is not appropriate since anaerobic energy is produced even at resting levels. As exercise gets more intense but still very much below the point that is designated as the "anaerobic threshold" anaerobic energy increases even though very little additional lactate may show up in the blood. If the athlete is well conditioned, most of the pyruvate* produced by the anaerobic system is utilized immediately for aerobic energy. In these athletes there will be little indication of increased lactate production even though the anaerobic system is being actively utilized. Also above the point that is designated as the "anaerobic threshold" there is still a steady increase in the use of aerobic energy till VO2 max. Thus, the use of the term "anaerobic threshold" is a misnomer because there is no sudden switch to anaerobic metabolism and there is a continued increase in the use of aerobic energy. Something completely different is happening at this point.

*Pyruvate is the end product of the anaerobic system called glycolysis. Glycolysis (fermentation) is what one is referring to nearly all the time they use the term anaerobic. Pyruvate is (is what glucose first splits into, that is split in half) what either immediately used (combusted) for aerobic energy in the cell (mitochondria) or converted into lactate (fermented into lactate in the cytosol). Very little pyruvate remains as itself which is why lactate is always the term used.

- I will show you how the fermentation – aka glycolysis - works visually in a simple way.

A quick history of thresholds.

In 1959 Wildor Hollman of the German Sports University in Cologne presented a paper on what he called "point of optimal ventilatory efficiency" at the Third Pan American Congress of Sports Medicine. The presentation was based on the author's hypothesis that the ventilatory and lactic acid threshold exists and how to determine each. In 1964 Wasserman and McIlroy used the term "anaerobic threshold" to describe similar phenomena and the term "threshold" became popular internationally. In the early 1970's, Alois Mader, was working with runners in East Germany and discovered that when these runners used a pace faster than the one that generated 4 mmol/l in a progressive exercise test that they quickly became exhausted. When the runners ran at a slightly slower pace they were able to continue running for an extended period of time. Mader escaped from East Germany and went to work with Hollman at the German Sports University in Cologne and popularized the 4 mmol/l lactate measurement. At the same time some researchers were using the term "maximum steady state" but had not yet connected it with lactate levels. In the late 1970 two German researchers, Kinderman and Keul started using the term maximal lactate steady state to describe the point where an athlete could not go any faster or harder without proceeding to exhaustion. Since that time the term "threshold" and "maximal lactate steady state" have become part of the training and testing lexicon. In 1981, Bertil Slodin, a researcher at the Karolinska Institute in Stockholm and a Canadian Ph.D. student there named Ira Jacobs, used the term "onset of blood lactate accumulation" or "OBLA" to refer to effort level in runners that corresponded to the point at which blood lactate begins to increase exponentially. A blood lactate level of 4 mmol/l was associated with this point and in most instances today *"OBLA" means a 4 mmol/l blood lactate concentration.* (Emphasis added by Ed) All these researchers quickly realized that the lactate level at which this threshold took place varied substantially between athletes while the myth has persisted that they said the 4 mmol/l level was the actual threshold level.

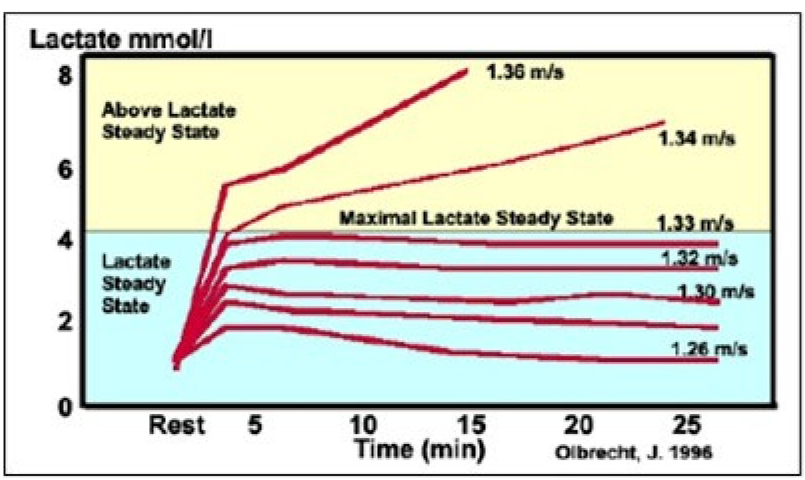
What is the currently accepted use of the term "anaerobic threshold"?

The most common use of the term "anaerobic threshold" is to describe a phenomenon that takes place in all athletes - namely the maximal speed or effort that an athlete can maintain and still have no increase in lactate. At this speed or effort, lactate levels in the blood remain constant. Any increase in effort or speed above this level will cause lactate and its associated high acid levels to increase steadily. This will eventually force the athlete to slow down or stop. The time to cessation or slowing down will depend upon how far the athlete is above the maximum steady state effort, the event the athlete is competing in, the type of athlete (strength or endurance) and conditioning.

It is possible for the athlete to exceed the anaerobic threshold level by small amounts and still exercise or compete for a substantial period of time, sometimes up to 25-30 minutes. The lactate levels will gradually increase in the blood but will not stop exercise for this time. However, substantial increases above the anaerobic threshold will usually shut down the athlete very quickly, often in as little as 20-40 seconds.

Because the anaerobic threshold represents a point where the lactate in the blood reaches a maximum steady state and is an equilibrium between lactate production and lactate clearance, we like two other terms better. The first is maximum lactate steady state (MLSS or MaxLass). This emphasizes the steady state and equilibrium concepts. The second is "lactate threshold" (LT). This retains the threshold concept but puts the emphasis on "lactate" and not "anaerobic". Both of these terms describe the same point of exertion.

The following chart illustrates the concept of a maximum lactate steady state. The swimmer below is able to maintain 1.33 m/s with a constant lactate level of about 3.8 mmol/l. At 1.34 m/s the swimmer is able to continue for an extended time as lactate slowly builds up and finally stops between 20 and 25 minutes. At 1.36 m/s the swimmer stops after 15 minutes. The maximum lactate steady state lies somewhere between 1.33 m/s and 1.34 m/s. For practical purposes it is assumed that the lactate threshold or maximum lactate steady state is 1.33 m/s.



What other terms are used to express this concept?

Many have used other terms such as the individual anaerobic threshold (IAT) and the "onset of blood lactate accumulation" (OBLA). The term IAT (Individual Anaerobic Threshold) has become popular in contrast to the original assumption of many that the anaerobic threshold nearly always took place at blood lactate levels of 4 mmol/l. Several sports scientists wanted to emphasize that the anaerobic threshold or MLSS takes place at different lactate levels for different athletes and that using a fixed level of 4 mmol/l for everyone was very misleading. In fact IAT's or MLSS's range normally from 2 mmol/l to 6 mmol/ with some people outside this range. Also MLSS's vary between sports for the same individual. So triathletes cannot use a fixed lactate level to determine their MLSS for each of the sports in which they compete.

Despite all the problems with the term "anaerobic threshold" the abbreviation AT has become an accepted part of training terminology. It will probably not go away for a long while because it remains a favourite with coaches, athletes, the press and even a lot of sports scientists. However, the term "lactate threshold" or LT is now becoming more popular. This has happened in the last 5 years.

What is the mechanism behind the lactate threshold?

Below the lactate threshold most of the lactate produced is being used as fuel for aerobic energy some place in the body.

Again, I will detail this visually - later - to clarify what this really means.

It could be used very close to the muscle generating the lactate or carried by the blood stream to other muscles and be used for aerobic energy. It is also used by the heart and some is converted back to glycogen. Physiologically the body as a whole is in equilibrium between lactate production and lactate elimination. The rise in blood lactate levels above resting levels as exercise intensity increases is an indication that some muscle fibers are not able to handle all the exercise load aerobically. The excess lactate produced from these muscle fibers moves to areas of lower concentration such as the blood stream, neighboring muscle fibers and the space between the muscles. Other muscle fibers have plenty of excess capacity for aerobic energy and these fibers can use the lactate produced by the fibers with limited aerobic capacity.

When we measure the lactate in the blood stream we are observing the movement of the lactate from muscle fibers that produce the lactate to those parts of the body that can utilize it. As exercise intensity increases the body reaches a point where it cannot utilize all the lactate produced. Above this point, which we call the maximum lactate steady state (MLSS), anaerobic threshold (AT) or lactate threshold (LT), the athlete is not able to eliminate lactate at the same rate as it is produced. As a result lactate starts to accumulate rapidly.

It should be noted that the rate at which lactate accumulates above the threshold varies. Generally, the slower the rate of lactate accumulation above the threshold the better the performance in long distance events. For shorter competitions such as those found in swimming, rowing, track cycling and running (events 5000 meters or under), the ability to utilize the anaerobic energy system to a high level (produce lactate quickly) is important.

How can one change the lactate threshold?

With training the lactate threshold will change primarily for three reasons;

- **Illustrated all this in Lessons 20, 21, and 22 in *The Physical Rules***

- lactate utilization increases (for three reasons a, b, c)
- lactate production declines
- lactate clearance increases. Here's how it works:

1. Lactate Utilization Increases –

Training can affect the utilization of lactate primarily in two different ways. However, to better understand the following discussion you should remember that lactate is produced from pyruvate and pyruvate is the end product of the anaerobic process. See the diagram below.

a. First, better oxygen utilization. With certain types of training there are adaptations within the muscle fiber that let it utilize more of the available oxygen. These changes within the muscle are physical as well as chemical. This higher utilization of oxygen means more of the pyruvate will be used for aerobic energy. When this happens less of the pyruvate will be converted to lactate. Often there is plenty of oxygen available in the muscle fiber but the fiber does not have the capacity to process the pyruvate aerobically. Changing this condition is one of the fundamental objectives of training. (#1 on Chart below)

b. Better oxygen delivery - Other types of training can bring about adaptations in the cardiovascular system, making it stronger and more efficient. This enables delivery of more oxygen to the muscles and at a faster rate. There is considerable evidence that as more oxygen is delivered to the muscles, less lactate is produced. This doesn't mean the anaerobically supplied energy decreases with improved oxygen uptake (the same amount of pyruvate is produced). It means more of the pyruvate will be used in the aerobic process and thus less will be converted to lactate. So for the same amount of anaerobically delivered energy less lactate will be found in the blood stream if the oxygen to the muscle increases. (#2 on Chart below)

c. One of the main adaptations that facilitates oxygen delivery is more capillaries. (which means more blood too – more plasma or increase of blood volume overall) Another change that increases oxygen delivery is ~~an increase in the proportion of red blood cells to plasma in the blood~~. (that is incorrect – an increase of plasma results in a proportional decrease of hematocrit)

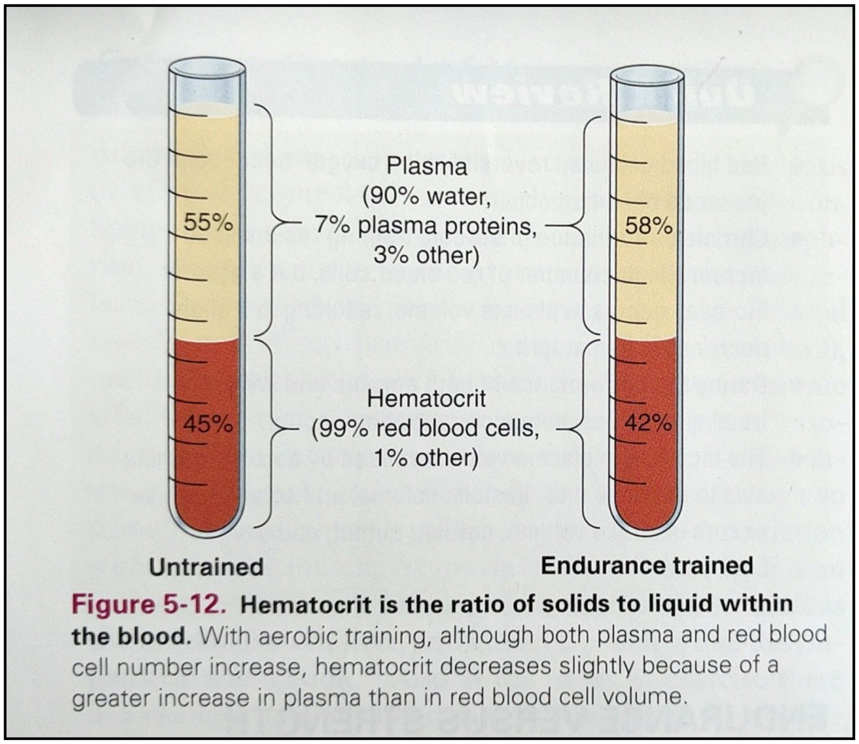


Figure 5-12. Hematocrit is the ratio of solids to liquid within the blood. With aerobic training, although both plasma and red blood cell number increase, hematocrit decreases slightly because of a greater increase in plasma than in red blood cell volume.

The ~~higher the percentage of red blood cells~~ **just more red blood cells means…** the more oxygen that can be delivered to the muscles. Some types of altitude training **(and blood doping)** have an effect on the oxygen carrying ability of the blood.*

***See Lesson 20 *Physical Rules* right side page**

Despite the better oxygen delivery, some lactate will be produced in muscles that receive plenty of oxygen because of other reasons.

2. Second - Pyruvate Production decreases.

This happens either because adaptations cause more fat to be used or because anaerobic capacity decreases.

More use of fats, less production of pyruvate. There will be less production of pyruvate as the muscles adapt to use more fats as fuel for aerobic energy. The higher utilization of fat means there is less need for glycolysis and consequently less pyruvate is produced. Certain types of endurance training enable the body to process fats easier. (#3 on Chart below) It should be noted that this adaptation does not imply that the anaerobic process is not as strong, just that the signals that activate it are not as frequent. This is in contrast to the next situation where anaerobic capacity is actually lower.

Lower anaerobic capacity, less production of pyruvate, Some types of training actually change the anaerobic capacity. In fact some coaches and sports scientists believe this is the main reason for short term changes in the lactate threshold. When this happens the lactate threshold will automatically change because pyruvate production is changed. When the anaerobic capacity is lowered less pyruvate is produced for a given effort level. Thus, the lactate threshold will increase without any change in the ability of the body to process aerobic energy or to shuttle lactate. When the body is faced with less pyruvate being produced, less will be converted to lactate at any given effort level. Similarly, an increase in the anaerobic capacity will lower the lactate threshold without any change in the in the ability of the body to process aerobic energy or to shuttle lactate. In this case the body has to deal with more lactate. The lactate threshold is always an equilibrium between lactate production and lactate elimination. (#4 on Chart below)

It is thought that the anaerobic capacity of an athlete is innately capped. **Genetically. This really means once you train – you reach your potential – and this is the reason why some people argue we cannot increase VO2 max. However, if you are detrained or out of shape, your VO2 max DOES drop. Then you must train to increase it back to your potential.**

There is a maximum rate of anaerobic energy production which the athlete seems unable to exceed. However, certain types of training affect the rate at which the anaerobic system can produce energy. Are these contradictory statements? No. It seems that the anaerobic capacity can be lowered from its innate maximum by specific types of training, usually associated with endurance training. High volume low level workouts will suppress the anaerobic capacity as well as long hard workouts near the lactate threshold.*

***This is concomitant with some fast twitch fibers (likely tweener types) switching to slow oxidative fibers**

The anaerobic capacity can be brought back to its innate levels by high intensity training well above VO2 max. This will cause the lactate threshold to be lowered. This is not something an endurance athlete would want to do before an important race but swimmers, rowers, runners, speed skaters, track cyclists etc are very interested in having a high anaerobic capacity for important competitions.

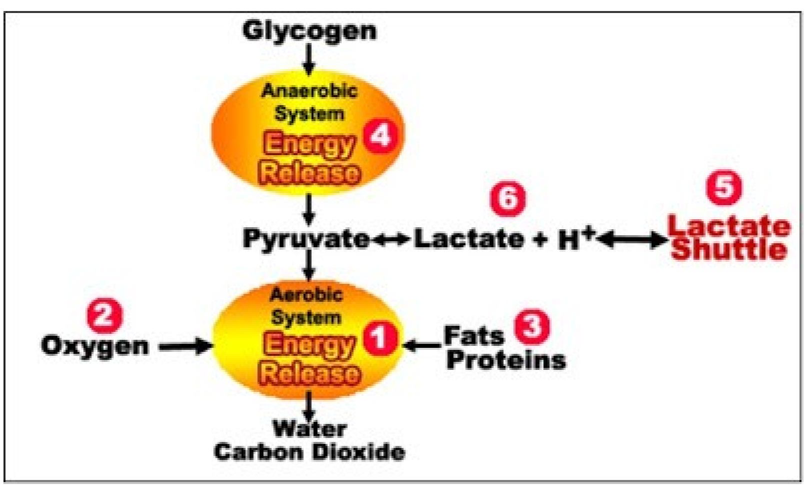
There have been studies of swimmers which have shown that there is no improvement in the lactate threshold late in the season as important competitions get near. Several prominent sports physiologists have then said that this shows that the lactate testing has little relevance for swimming. Nothing could be further from the truth. What is happening to swimmers is that late in the season training intensity increases substantially and this raises anaerobic capacity back to innate levels. This has the effect of lowering the lactate threshold or keeping it at about the same level. If coaches are not aware what is happening to the anaerobic system then they could prescribe the wrong training for the athletes. By the way this may be a controversial area. I say "may be" because there is not much written on it and so it hasn't been discussed much. It is definitely not considered a factor in why the lactate threshold changes by many sports scientists. However, it is consistent with what a lot of coaches observe in their training programs. Some sports scientists are starting to write more about it.

3. Lactate Clearance Increases

Training helps the body becomes more efficient at removing lactate from the producing muscles and shuttling it to other parts of the body where it can be used. This eases the acid levels in the producing muscles and thus lets them operate at a higher energy level before producing the acidosis levels that slow down energy production. (#5 on Chart below)

Also training for better oxygen delivery can help the lactate shuttle as the increased capillary system will help clear the lactate out of producing muscles and into the blood stream. The same adaptation facilitates the transfer of lactate from the blood to other muscles for elimination.

Buffering - The muscles can be trained to buffer some of the acid accumulating in the producing muscles. The hydrogen ions causing the problems with contraction are neutralized and this allows even more lactate to be produced before there are problems with contraction. However, it probably does not affect the threshold since it does not slow down lactate production. Buffering enables the athlete to compete for a longer time at effort levels above the threshold. Little is written about how to train this buffering capacity though it is thought to take intense workouts to increase the buffering capacity of the muscles. Coaches often prescribe intense workouts called "lactate tolerance" sets to do two things; 1) get the athletes accustomed to the pain that accompanies high acidosis and 2) increase the buffering ability of the producing muscles. (#6 on Chart below)



Detraining - Lower training levels or stopping training altogether can reverse a lot of these processes and this will also affect the lactate threshold.

How does one train to change the threshold in all these different ways?

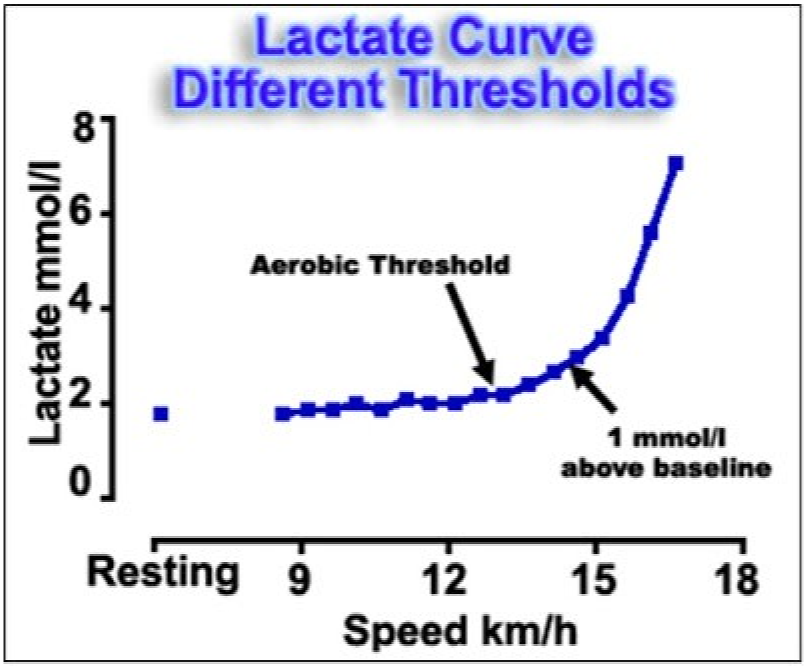
This is an interesting question since we haven't seen anyone address it completely. There is a lot of advice on how to change the threshold but none approaches it on the basis of changing six different processes. Also one type of exercise may work on more than one of the six processes. For example, whatever causes capillaries to increase will reduce the production of lactate but will also help the lactate shuttle. Also different types of training may be necessary to effectively change a process. To lower the anaerobic capacity may require a combination of intense workouts near the lactate threshold plus long slow training. Obviously what will work for the regional level athlete may not work for the athlete preparing for Olympic trials since highly trained athletes may have maxed out on several different adaptations. Also what may work for enhancing one of these factors may hinder another since often training exercises are not surgically precise.

The closest we have seen anyone answer this question is the book by Jan Olbrecht which looks at training exercises based on how they will change specific aspects of conditioning. It is a book on swimming but provides a template or schema for developing training exercises that are appropriate for any endurance sport. Also Olbrecht's book emphasizes that these adaptations have to be timed in a precise sequence. Some take several months and even years while others can be done in a few weeks once some of the other adaptations have taken place. Olbrecht works with swimmers, triathletes, runners, rowers and soccer teams. His athletes won 28 medals at the Athen's Olympics.

Are there other thresholds?

There is the point at which the baseline lactate rate starts to rise. (A baseline level is the amount of lactate generated at a slow pace used for recovery or warm-up. See the chart below.) Some have called this the "aerobic threshold." This particular point has some meaning because it represents an effort level at which the lactate in the blood starts to rise. Some have suggested that this point is the effort level at which the body starts to recruit fast twitch fibers. Fast twitch fibers generally produce more lactate than slow twitch fibers. However, this point responds to training just as the lactate threshold does so what is going on in the body at this point is probably a combination of things, one of which may be a recruitment of new fiber types. But it is too simplistic to describe this point as the point where fast twitch fibers are first recruited.

If you want to get really confused, some sports scientists have identified a third threshold which they identify as the effort level that generates 1.0 mmol/l of lactate above the baseline. Some have called this pace or effort the "lactate threshold". However, we use "lactate threshold" to mean the maximum lactate steady state and we will just refer to this third threshold as 1.0 mmol/l above baseline. This lactate level is approximately the lactate level that a marathoner maintains during a race and is definitely below the MLSS for most athletes.



You will notice on the chart above that we did not indicate the lactate threshold. That is because there is no clear point on the curve that can be identified with this effort level. The other two effort levels are more easily identified which is one of the reasons they are popular. However, they require that several lactate readings be taken in order to clearly identify the baseline and where it starts to rise.

Different training programs use these different levels. Coaches and athletes should know what each means in case they hear them used. However, the biological processes at the lactate threshold, the point 1.0 mmol/l above baseline and the point at which lactate starts to rise may be quite different metabolically from athlete to athlete. We identified 6 processes that affect the lactate threshold. It is unlikely that two athletes with the same lactate threshold have identical physiological profiles. In other words if you compared two athletes at each of these thresholds you may find very different processes going on within the athletes even if the effort levels at the threshold are similar. For example, two athletes at the lactate threshold may be using the aerobic and anaerobic systems quite differently.

The coach is trying to maximize the energy produced for these two athletes during a competition and not necessarily manipulate a particular threshold. Thus, the coach tries to find the optimal balance between aerobic capacity and anaerobic capacity depending upon how the competition will unfold and the current conditioning level of the athletes.

Are these thresholds important?

This is an interesting question. Since there is a lot written about them it must be for a reason. Also we spent a lot of time above discussing how to train to change the lactate threshold. We have just mentioned that the pace that is 1.0 mmol above the baseline lactate readings corresponds roughly to the pace that a marathon is run at. Hence it is very useful for distance runners to know this point and judge their progress by how much this point is changing with training. A well trained athlete can run, bike, swim or row for several hours at this pace and not slow down. Ironman triathletes and road cyclists also compete at a pace close to this level or just below it.

While knowing the lactate threshold is important for competition, knowing the threshold exactly may have less relevance for training despite our long discussion above. Above the lactate threshold there will be an accumulation of acid in many of the working muscles because production is outstripping clearance and this is extremely relevant during many types of competition. However, during training it is not as important to know or act on the lactate threshold pace or effort even though much of training has the objective to change it. First, there is nothing special, biological or metabolic, happening at the lactate threshold or at any other threshold. There is no new fiber group being recruited or transition to something different (even though the term "threshold' is used the processes are all continuous). The important thing that happens above the threshold is that the increasing acidosis will shut down the muscles in a short time. Thus the total volume of possible exercise will be less. Also, frequent efforts at levels above threshold may damage the muscle cell structure and end up lowering aerobic capacity instead of increasing it.

For the "more is better" school the lactate threshold represents the highest effort level that the athlete can maintain for a long time. Thus, prescribing workouts at this level will provide the most difficult stimulus the body can handle for an extended period of time. This approach has some problems.

Namely,
- working out at the lactate threshold will not recruit all the fibers in the muscles used for a sport and thus not train every muscle that will be needed in competition. The percentage of fibers recruited at the lactate threshold will vary a lot between athletes. One athlete who has a LT at 70% of VO2 max will not use as many fibers at LT as the athlete who has an LT at 93% of VO2 max. As we mentioned above what happens at LT may not be the same for each athlete. Thus, coaches have to design workouts for each athlete based on each conditioning profile. Even two marathoners who have the same LT pace may have very different conditioning profiles. The two may have very different anaerobic capacities and should train differently because of this.

One way to train all the fibers is to do interval training at high intensities near VO2 max. This way the athlete whose LT is 70% of VO2 max can train all the fibers.

- Too frequent extended workouts at the LT is a formula for over-training if used too frequently. What is too frequently? This is a murky area. But a runner who completes a marathon will usually do so at a pace that is lower than the lactate threshold. This runner often needs several weeks to recover fully because of muscle damage. Very few would prescribe a marathon as a workout. However, some coaches/training advisers recommend frequent LT workouts and intervals above threshold. These workouts accumulate substantial mileage during a week and often come close to subjecting the body to the same volume and intensity as a marathon. Even if spaced out every 2-3 days such workouts and competitions done too frequently will break down rather than build up aerobic endurance. If the purpose or training is to break down cellular processes and then give them time to rebuild to a higher level, it is hard to see how continual high intensity workouts will allow the rebuilding process.

Is measuring these thresholds necessary?

The answer is NO! Some very successful coaches have questioned the value of finding the lactate threshold. They don't claim it doesn't exist or that it isn't a good predictor of endurance. They say it is not necessary to measure it to prescribe good training. Their positions have been stated above but to summarize them:

The lactate threshold is difficult to measure and takes too much training time to find it. There is a much a simpler approach, also using lactate testing, that works just as well.

There is no proven benefit to train at the threshold versus training at several different levels. In fact given that there are a multitude of adaptations an athlete desires it is important not to be pre-occupied with training at the threshold.

The threshold will mean different things to different athletes and they are not always obvious. For example, a well conditioned top endurance athlete will have a lactate threshold at an extremely high effort level. This effort at threshold will be very stressful on the aerobic system since the athlete may be close to VO2 max at this point. Because the aerobic system is highly developed for this athlete, it will be using most of the pyruvate produced by the anaerobic system. There will be little lactate in the blood till the anaerobic system is highly engaged. Thus, at threshold the elite athlete is utilizing not only the aerobic system at a high percentage of max but also the anaerobic system at very high levels. Both systems are under high stress.

For regional athletes who compete in local endurance events and have a much lower aerobic capacity there may not be too much demand on their aerobic system at the lactate threshold. They will not be very close to VO2 max at LT and it is highly unlikely that they will stress their aerobic system at threshold as much as the elite athlete will. Also it doesn't take much activation of the anaerobic system to produce the lactate that will be in the blood at threshold. Hence the regional level athlete is not nearly under the same stress as the elite level athlete at threshold. This sounds counterintuitive to most people but is easily understood once you realize what causes the threshold.

This point of view has evolved from the experiences of many sports scientists from the University of Cologne.

How long can an athlete exercise at these thresholds?

This will obviously vary by athlete depending on training level, types of recent workouts, muscle composition, diets, tolerance for discomfort, the environment and other factors.

- The pace just below 1.0 mmol above baseline can be sustained for hours.

Ed's Note: Sustaining for hours is like walking the Appalachian Trail

The athlete is burning a high percentage of fat at this pace and there is enough fat in us for hours of exercise (even those athletes with low body fat). A lot of training for long distance endurance athletes is aimed at training the muscles to burn more fat.

- Most athletes can usually train at the lactate threshold (LT or MLSS) for about 60 minutes continuously.
- Some can train up to 90 minutes.

The limiting factor is fuel for energy (glycogen) and this will depend mainly on recent workouts and diet. When the athlete runs very low on glycogen the muscles cannot sustain the LT pace or effort and will slow down. It will be 36-72 hours before glycogen stores are fully replenished.

Let us illustrate the importance of glycogen with two ice hockey games.

This is a great story to understand glycogen depletion

A couple of years ago, four teams were competing for the NCAA hockey Championship. The semifinals were on Friday and the finals were just a day later on Saturday for financial reasons. Hockey doesn't attract much of a television audience so most money generated by a championship is through attendance. People will not wait around a few extra days for a championship game. Well, one of the semi-final games finished in regulation with a winner while the other went to three sudden death overtimes of 20 minutes each. If you've ever watched a good hockey game you know it is the most intense sport on the planet. During a sudden death playoff game there is only one gear and it is all out. The teams that played the three overtime game were using as much anaerobic energy and glycogen as possible. During the finals, one day later, the team that won in regulation walked over the team that played three overtimes. One commentator said they must have had a letdown psychologically after the dramatic overtime win. Nonsense! They didn't have any glycogen to fuel the high intensity efforts needed for hockey.

Similarly, an athlete that does an extended workout at LT or higher will be unable to complete a similar workout until the body's glycogen is replaced, often several days. Not every athlete is the same on this. But just because an athlete can do a long LT workout it may not necessarily be a good thing to do.

Some coaches caution that training sessions at the lactate threshold for a prolonged time can be very counterproductive.

Should an athlete train at levels higher than LT?

Certainly. The real question is how much training above the LT should an athlete do and at what level. This is a very controversial area.

Ed's Note: The ultimate training is to know how this works and train your self - YOU are the instrument you play and NOBODY knows your body as well as you do.

There are studies that show high intensity training provides excellent results and there are studies that show that lower levels produce the best results. There is research that shows that the best aerobic training is workouts near VO2 max but that you cannot do too many of them. A lot of what gets published is based on research studies done by academics and is based on 8-12 weeks of training because that is when academics have students to use as subjects. Basing long term training objectives on this type of information is risky.

One coach said that if you are in a hurry, then you will have to include a lot of high intensity workouts. There is no other way to train muscle fibers that don't get recruited till high intensity efforts.

Another coach who took a different tack said that you are "training to train". Early season workouts are mostly below threshold so that the athlete will develop the base to do more intense workouts later in the season or in later years. He described training like a ladder. You have to train at the first rung before you can attempt the second step. As you move up the ladder your body is better able to handle the highly intense training that will eventually come. This obviously will depend on the sport, the amount of time available for training and the timing of important competitions.

Before leaving this question we refer the reader back to the diagram above which illustrates the various factors affecting the anaerobic threshold. There are so many different factors which affect performance (and the diagram doesn't cover them all) it is irresponsible for someone to say this is his or her "favorite workout" in the sense that this is what will condition the athlete better. These may make good magazine articles but they don't make good sense in training.

No workout, no matter what the intensity or the distance, can hope to train more than one or two of the factors affecting performance. Successful training is the culmination of a variety of different types of training. There are so many adaptations that training must provoke and each of these adaptations needs a different intensity and duration. Giving the training a different intensity is like putting an address on a letter. If you only put one or two addresses on the letter it will only go to one or two places. By using only a couple of different intensities in training only a couple of different adaptations will happen.

The purpose of testing and other assessment procedures (competition results and success in training) is to tell the coach and athlete what adaptations are necessary for further improvement. **Just another form of feedback.** Then the athlete's "favorite workout" will be the one that provokes the adaptation to realize this improvement and not what is a popular workout.

What type of tests are done to find the lactate threshold?

There are several types of tests to measure the lactate an athlete produces. These tests are often referred to as protocols. The most common type of test is what is called a graded exercise test. It has several other names such as a step test or a progressive exercise test. An example of such a test is the chart above of a runner on a treadmill. Essentially this test is a series of exercises at progressively higher intensities.

Stage	Time or Distance	Pace	Lactate mmol/l	Heart Rate	RPE
Rest					
1					
2					
3					
4					
5					
6					
7					
8					
Exhaustion					
2 min rec					
4 min rec					
10 min rec					
20 min rec					

- The athlete will run on a tread mill or a track, ride a bike on a track or an ergometer, swim several laps in a pool, row on an ergometer or complete some other form of steady state exercise. They will start at a low level of effort. After completing the first stage, the athlete completes a second step at a higher effort level - and so on for each next step at a higher intensity level (speed or steeper incline). The athletes usually complete the test by attempting a level of exercise that will cause them to reach exhaustion but this is not necessary and may actually be counterproductive. At every step and at exhaustion, a lactate reading and other measures are taken.

The measurements taken are lactate readings which can be easily done with a portable lactate analyzer; heart rates which many athletes and coaches measure with a heart rate monitor; and perceived exertion which the athlete estimates. Usually, a coach or a trained assistant with a little practice takes the measurements while the athlete is performing the exercise. We know of experienced athletes who have conducted these tests by themselves on a track or an ergometer. However, most athletes have trouble taking their own lactate readings when they are substantially above threshold.

From this testing a coach can estimate the lactate threshold. We emphasize the word "estimate". This type of testing will narrow down the LT range and experienced coaches will be able to come very close to it by knowing the athlete and seeing the shape of the curve. Coaches should do a confirmation test of the LT to be sure. This is just a steady state workout at the estimated LT and is best done in a field setting. The coach will take a couple of lactate readings during the workout to confirm that the athlete is really at threshold.

Lactate Threshold Test Procedure

http://wayback.archive.org/web/20120221171225/http://www.boulderperformancelab.com/tests

The Lactate Threshold is used to determine an athlete's quantitative performance at their theoretical (or close to it) race pace. Depending on the fitness level of the athlete, the Lactate Threshold effort level is approximately equivalent to a 45 minute to 90 minute race exertion. A highly trained athlete (top pro level) might be able to hold LT efforts for 90 minutes or more. A novice athlete might only be able to hold LT for a maximum of 45 minutes. Typical recreational-level athletes can hold LT for about an hour.

The athlete warms up on the treadmill or bike for 15 minutes at light load or speed. The load or speed is linearly increase at three minute intervals (3.5 min for run). A blood lactate reading is taken, heart rate recorded and Rating of Perceived Exertion (RPE) is documented at the completion of each three minute interval. This process is repeated until the Lactate Threshold is reached (inflection point). An additional two data points beyond LT are recorded to ensure an accurate graph.

The start point, and wattage/ speed steps are variable based on the athlete's individual fitness level (bike wattages are from 10-20 watt steps, treadmill speeds are from .3-.5 mph steps).

Dean Karnez Debunk Video: https://youtu.be/6UtYbJvE6cE

Lance Armstrong Lactate Testing: https://youtu.be/1QcIHRUELuY