The Winning Mindset

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Understanding Lactate Threshold Training: 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 3-part series on understanding **Lactate Threshold** and how to train and improve it. The first article, **available on our website**, is Scott providing an introductory lesson aimed at a reasonably educated, first year junior high distance coach with a trio of committed athletes on her squad.

This article, Part 2, is aimed at a **moderately successful high school coach** with about five years of experience. He has a female runner who recently ran a 5:05 mile, and two males that have run between 4:29 and 4:40. This coach has a basic understanding of Lactate Threshold training, but he confuses some terminology and inadvertently mixes up workouts.

Again, many coaches would benefit by breaking down each of these LT articles, taking detailed notes, and exploring the concepts further.

The third article in this series will expand the discussion to the collegiate level with a few more accomplished 5K athletes.

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

Coach Christensen's Response for Part 2:

Fatigue limits performance in athletes. Performing an activity in a fresh condition is much different from performing the same exercise while under physical duress. In distance runners, there are many causes of fatigue: scarcity of available fuel, limitations at the neuromuscular junction, central nervous system compromise, heat build-up, dehydration, and acidosis, among others. These factors seldom appear in isolation and will often combine to contribute to distance runner fatigue in a race or workout. Degrees of fatigue chiefly depends on athlete fitness, length of workout or race, and environmental conditions.

For races in the 800 meters to 10,000 meter range, the main contributor to fatigue will be due to acidosis. On the shorter end, the lactate/hydrogen ion build-up will be high over a short amount of time, while on the longer end the lactate/hydrogen ion build-up will be low but over a longer length of time. No matter the rate of build-up, the effects of acidosis will be the same in the end for all of these races.

Acidosis originates from glycolysis which is the energy-producing mechanism in the anaerobic division of an animal's energy system. Glycolysis is a rapid-sequence process of 11 enzyme-catalyzed reactions in which glucose or glycogen stored in muscle is reduced to lactate and hydrogen ions in the absence of oxygen while releasing ATP re-synthesis energy. Glycolysis requires no special cell organelle, as it takes place throughout the cell cytoplasm in a very rapid cyclic reduction process. Simultaneous with glycolysis, ATP is resynthesized from ADP using energy captured from the reduction of the glucose molecule, enzymes, and loose phosphate molecules. One molecule of glucose ultimately produces 2 ATP molecules during glycolysis. These ATP molecules then proceed to contraction protein filaments called myosin, where they are used to contract the muscle. As previously stated, the products of the glycolysis reaction beyond energy, are lactate ions ($C_3H_5O_3^-$) which are base molecules, and free hydrogen ions (H^+) which are chemically an acid by nature. Like any acid, from acid rain to battery acid to vinegar; the acid reacts against tissue, and is caustic to living protein. Chemists measure the strength of an acid on a logarithmic scale known as the pH scale. The scale is graded from 1-14 with water neutral at 7. Living tissue in humans is measured at about 7.2 pH. As hydrogen ions accumulate in the cell, the pH of the cell begins to drop. It could drop so low (pH 6.5) that the enzymes present in the cell that facilitate the thousands of biochemical reactions begin to be ineffective and eventually cease their activity. This is called anaerobic glycolytic fatigue in the muscle, which could lead to anaerobic glycolytic energy system exhaustion. The muscle can no longer muster force production due to the high acidity (low pH) in the cell. This condition is termed acidosis.

The ability of a person to withstand the effects of acidosis is a fascinating topic of research and discussion. There is a psychological component to it because there is physical pain involved, and the pain threshold is an individual characteristic. As pH drops in the body, the pain mechanism kicks in as a warning from the central nervous system to protect the organism. Some runners can mentally tolerate a high level of pain, others can tolerate a low level of pain over a great distance, a few can do both, while many others that still enjoy running, prefer to avoid pain altogether.

Most of the effects of acidosis on race performance are physical. Since the result of glycolysis is the deterioration of enzyme activity in cells, there reaches a point where mental strength just cannot overcome the shut-down mechanisms of the energy and muscular systems of the body. As a result, many of the outcomes of distance runner training are targeted to delaying these shut-down mechanisms through structural and chemical adaptations that occur at the tissue level of the athlete's body. Chiefly, accumulating hydrogen ions have to be either buffered more effectively, or they have to be drained more efficiently from muscle cells. If done right, distance training can be prescribed to help in both areas.

Acidosis damages protein cell structures as well as enzymes. Damage may be found to the nucleus, membranes, and even mitochondria. As mitochondria are damaged or destroyed, the aerobic division of the energy system is harmed. Since the processes of the aerobic division are the most important for ATP re-synthesis in distance races greater than 800 meters, losing mitochondria is a performance problem. A careful eye must watch overtraining so the daily levels of acidosis, measured through lactate production, matches the needs of the race length. High lactate producing days are needed often for high lactate producing races like the 800 and 1600 meters. High lactate producing days are not needed as often for lower lactate producing races like the 5,000 and 10,000 meters (table 1). If high lactate days are carefully monitored, then mitochondria damage which is most important in the longer races is minimized.

Activity	Measured Lactate Value
Rest	.08-1.5 mmol/L
Jogging	1.8-2.2 mmol/L
LT	2.5-3.5 mmol/L
10000 meters	4.0 mmol/L
5000 meters	9.0 mmol/L
3200 meters	11.0 mmol/L
1600 meters	15.0 mmol/L
800 meters	21.0 mmol/L

Table 1. The lactate production levels for various races at an exhaustive pace. The extent of acidosis fatigue can be monitored through lactate production levels.

All distance training should contain lactate threshold (LT) exercises. LT training produces amounts of lactate/hydrogen that slowly build-up in muscle cells. Mitochondrial damage is minimal because the hydrogen ion production rate barely exceeds removal rate so the aerobic system is preserved. Because pH in the cell will begin dropping slowly, the training stimulus is weak, so it must be carried over a substantial length of time. It can be carried as long as 50-70 minutes (15 kilometers) but is usually held to 25-35 minutes (4.5 mile tempo run). This is the simplest form of LT training and only produces one stimulus type to facilitate adaptation to acidosis fatigue.

Lactate threshold training has a primary performance outcome of shifting the lactate performance curve to a faster pace (to the right on a lactate performance curve graph) in distance runners. In other words, a runner will run at a faster pace following LT training then they did before at the same level of acidosis fatigue. In order to do this, work sessions must be prescribed that produce different stimuli to both buffer and drain hydrogen/lactate from the cell better during exercise. Some workouts, like the tempo run, are targeted to stimulate storage of sodium bicarbonate in muscle cells that buffers or neutralizes hydrogen ions. Buffering delays the drop in muscle pH. Other workout types are designed to restructure muscle cell membranes so they have more pores to selectively diffuse hydrogen/lactate ions from the cell more rapidly. Draining lactate/hydrogen from the cell stops muscle pH from dropping.

Distance training needs to be monitored quantitatively. Descriptive terms like fast, medium and slow have little value when explaining intensity to a runner on how to proceed through a workout. Coaches use different means for quantitively measuring workout intensity such as heart rate monitors, lactate analyzers, and individual pace with a stopwatch. Monitors and analyzers do not work as well with big training groups for many reasons, but the individual pace can be effective for any size group.

When a runner has an accurate present-day value for their 3200 meter time to exhaustion, then many LT workouts can be devised. Different workouts to both stimulate the buffering and improve the drainage of hydrogen/lactate ions from the muscle cells have proven to be effective. A 3200 meter time is known to be the best value for measuring *aerobic power* or what is commonly termed $VO_{2\,max}$. If the 3200 meter time is reduced to per mile pace, then the value is considered present-day $vVO_{2\,max}$ pace (little v is velocity). This is a pace that is often used as both a numerical mark to fractionize LT workout pace as well as other aerobic training paces. Physiologists have correlated LT pace to be about 85% of $vVO_{2\,max}$ pace (range is 83-88%). A tempo run is usually done right at this value, other LT runs spread out from there as other percentages of $vVO_{2\,max}$ pace are prescribed for different training effects (table 2).

Training Term	Training Pace	Lactate Produced	Physiological Stimulus/Effect	Also Called
Lactate Run 3	89-92% $vVO_{2\,max}$	3.7-4.2 mmol/L	Lactate Drainage	Critical Velocity Pace (CV)
Lactate Run 2	83-88% $vVO_{2\,max}$	2.5-3.6 mmol/L	Lactate Buffering	LT Pace, Tempo Run
Lactate Run 1	78-82% $vVO_{2\,max}$	2.0-2.4 mmol/L	General Strength	Longer, Near-LT Runs

Table 2. The fractionization of $vVO_{2\,max}$ in setting up LT runs for different aerobic capacity training effects. The range of lactate production found around the LT must be fully stimulated through different training sessions.

The pace is the key to effective LT based workouts. As examples, let's look at a trio of emerging runners and some different workouts they might do to stimulate both lactate drainage and buffering to condition against acidosis fatigue.

1. Ethan is a high school junior and has a training age of three with the distance crew of an improving team. He has dropped his 1600 meter time from 5:33 to 4:40 over his first two years of serious training, but his 3200 meter time is lagging at 10:33 and his 5k is 17:40. Both Ethan and his coach are motivated to have him in on the top five of the cross country team this fall, but he needs to improve at longer distances. Let's diagnose Ethan and look at specific training. Ethan has both under-developed aerobic power and aerobic capacity. To address this, he should faithfully do $vVO_{2\,max}$ paced training sessions once per week beginning half-way through the general summer running period to address the former, and do LT paced runs bi-weekly beginning early in the summer all the way to the championship meets in the fall to improve the latter. When Ethan begins the LT runs he will have to first start with a

3200 meter test to determine his $vVO_{2\,max}$ date pace. Let's say on June 20, Ethan runs 10:50 to exhaustion for a 3200 meter time trial, so his present day $vVO_{2\,max}$ pace is 5:25 per mile. For the next five weeks, Ethan should do three spaced workouts at near LT pace, in this case, 82% $vVO_{2\,max}$, to build his aerobic strength (table 2). The distance of the three runs should each be seven miles. The pace for Ethan is set at 325 seconds (5:25/mile) divided by .82 for a workout pace of 6:36 per mile. His total time for seven miles should be 46:12. After five weeks Ethan will progress into bi-weekly runs that are specifically at his LT pace, but instead of seven miles, they will be shortened to 4-5 miles.

2. Katie is a junior and has been on both the high school varsity cross country and track teams for the past two years. She has run 5:05 for 1600 meters, 11:12 for 3200 meters, and 18:43 for 5000 meters in cross country. Her tempo run pace always correlates to her 85% $vVO_{2\,max}$ date pace and she seems to recover in 24 hours from the workout. As expected, her improvement has slowed a bit as she has gotten older. Let's diagnose Katie and look at specific training. Katie no doubt has a mature $VO_{2\,max}$ system already in place, so despite continued workouts at $vVO_{2\,max}$ pace, it is not going to improve much. Her aerobic capacity work, mainly done as long runs, are her favorite thing to do because they come easily to her. Typically, females are a couple of years ahead of males in $VO_{2\,max}$ development, and some more than that. If Katie is to get faster at distance races, then her best route to success is to try to raise her LT pace from 85% $vVO_{2\,max}$ to a value closer to 90% $vVO_{2\,max}$. Her LT paced workouts need to evolve from continuous tempo runs to critical velocity (CV) runs done as intervals (table 2). To address this, Katie should continue to do $vVO_{2\,max}$ paced training sessions bi-weekly beginning half-way through the general preparation period, and concurrently do CV paced runs bi-weekly at the same time; both all the way to the championship meets in the competition period. Like Ethan, when Katie begins the CV interval sessions she will first have to start with a 3200 meter test to determine her $vVO_{2\,max}$ date pace and then do the mathematics to determine CV pace. Let's say on January 10, Katie runs 11:40 to exhaustion for a 3200 meter time trial, so her present day $vVO_{2\,max}$ pace is 5:50 per mile. For the next fourteen weeks, Katie should do seven spaced workouts at her date CV pace, in this case, 89% $vVO_{2\,max}$, to improve her LT. The typical total volume for each of the seven sessions should be 4-5 miles done as intervals. The date pace for Katie is set at 350 seconds (5:50/mile) divided by .89 for a workout pace of 6:33 per mile, but she will not run a full mile at that pace, so one more mathematical division must be done. Katie's typical CV workout is 6 x 1000 meters with 90 seconds recovery between each repetition. Her calculated date pace for today is 6:33/mile or 4:06/1000 meters. As her 3200 improves throughout the year, the fractional CV pace will too. The workout distance and the recovery will not change throughout the season, only the pace will.
3. Jeff is a third-year distance runner on the high school track and cross country team and is a senior. He runs 52.8 seconds on the 4 x 400 relay as well as a distance race each meet. His distance race times are 4:29 for the 1600 meters and 9:53 for the 3200 meters. His goal is to win the conference 1600 meter race at the end of the season. Lately, in that event, Jeff has been right with the best runners in the conference at 1200 meters, but then fades over the last 400 meters and splits a 65 second last lap. Jeff has gone to his coach with the motivation to "get faster at the end of the race". He wants to do more speed work at practice. Is Jeff, right? Jeff is wrong. He is already "fast" enough and his 400 leg on the 4 x 400 relay bears that out. Jeff's real need is to be "fresher" with one lap to go. For that, he does not need more speed work, but more LT work. The *comfort zone* of Jeff's 1600 is not

comfortable at all and when he moves into the *critical zone* of the race over the last 400 meters he suffers. Let's diagnose Jeff and look at specific training. Jeff is well developed at tolerating lactate and hydrogen ions. His anaerobic capacity is really good for a high school miler. His $VO_{2\ max}$ is also good for a male his age. Jeff has an aerobic capacity problem and needs to shift his LT pace faster to keep the lactate/hydrogen build-up lower in the comfort zone of his 1600 meter race. To address this, Jeff must continue to develop his aerobic power by doing $vVO_{2\ max}$ paced training sessions once per week throughout the season, and concurrently do LT paced runs weekly to develop his aerobic capacity. Like Ethan and Katie, when Jeff begins the LT runs he will have to first start with a 3200 meter test to determine his $vVO_{2\ max}$ date pace. Let's say on April 4, Jeff runs 9:56 to exhaustion for a 3200 meter time trial (or a meet), so his present day $vVO_{2\ max}$ pace is 4:58 per mile. For the next six weeks, Jeff should do six spaced workouts right at LT pace, in this case, 85% $vVO_{2\ max}$, to improve his aerobic capacity. The distance of the six runs should each be five miles. The date pace for Jeff today is set at 298 seconds (4:58/mile) divided by .85 for a workout pace of 5:50 per mile. His total time for five miles should be 29:13. As his 3200 time improves throughout the season so will his LT pace. A series of workouts like this will allow Jeff to be fresher at 1200 meters and he should then get to within about seven seconds of his current best 400 for his last lap. In his case, a 60 second or better closing 400 meters.

Lactate threshold runs can be done in a variety of ways depending on individual need. The key to the work is first diagnosing where the weakness of the runner is and then designing workout sessions just below, right at, or just above date LT pace for each individual to meet these needs. The aerobic energy system is very robust and carries most of the load in distance races, so having it as developed as possible is crucial to success.