The Winning Mindset

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Understanding Lactate Threshold Training: Part 3 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.

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

In this article, Scott will add another layer to the discussion and discuss how **LT training** applies to an experienced **collegiate coach** who leads a competitive distance squad on the university's cross country and track teams.

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

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

Coach Christensen's Response for Part 3:

Lactate is produced in the muscle cells of the body on a constant basis. Quick, blink! You just produced lactate in the very small muscles of your eyelid. Because these sorts of everyday activities produce slight amounts of lactate, the body disposes of it quickly and efficiently by oxidation within the cell. However, if exercise intensifies above the lactate threshold (LT), lactate/hydrogen molecules begin to accumulate exponentially. Lactate oxidation continues, but cannot keep up with increasing lactate deposits. The lactate shuttle transports some of the extra lactate via the blood to the liver where it is filtered and enters the Cori Cycle as a precursor to hepatic gluconeogenesis and is converted to usable carbohydrate fuel once again. Some lactate ions flow to the heart and are used directly as cardiac muscle fuel. Whatever the case, lactate is one of the two molecules left behind when a glucose molecule in the cytoplasm of the muscle cell cleaves during anaerobic glycolytic respiration, with the other molecule a hydrogen ion. The loose hydrogen ion is the culprit of damage to the muscle cell and enzymes, ultimately causing performance fatigue.

In addition to oxidation, transport, and filtration of lactate, all humans have the ability to tolerate some hydrogen ion presence because of constant buffering reactions in the cell. Positive ions of hydrogen are in effect neutralized by negative ions of various substances found throughout the cytoplasm (Table 1). The most effective cellular buffering agent is known to be sodium bicarbonate and enhanced anaerobic glycolytic stimuli have been shown to increase stores of it in the sarcolemma of the muscle cell. Sodium bicarbonate results from quick chemical conversion of carbon dioxide through a carbonic acid intermediary conversion process in muscle tissue. The adaptive response for increased sodium bicarbonate storage is dictated by the training intensities of the runner, through the training law of specificity. Sea-level running at and just above LT pace results in up to 75% of the carbon dioxide produced in muscle tissue being converted to sodium bicarbonate.

Muscle Cell Buffering Agent	Untrained	Trained
Sodium bicarbonate	8.0 slykes	18.0 slykes
Hemoglobin	5.0 slykes	8.0 slykes
Proteins	1.4 slykes	1.7 slykes
Phosphate	0.3 slykes	0.4 slykes
Total	**14.7 slykes**	**28.1 slykes**

Table 1. The buffering capacity of blood components present in trained vs. untrained distance runners. Training was 12 weeks of sea-level combined zone mixed training. Slykes are a measurement of milli-equivalents of hydrogen ions taken up by each liter of blood at a resting pH value of 7.2.

Compared to many other mammals, humans are not fast runners, nor have the ability to hold speed very long before fatigue causes exhaustion. Physiologists call this the low lactate response (LLR). However, through chronic training sessions at LT pace and faster, humans can improve their individual LLR, mainly through increased presence of sodium bicarbonate molecules in muscle tissue. Since all distance races have a degree of anaerobic energy requirement, varying from very little in the marathon (mainly surges) to 50% in the 800 meters, it can safely be said that some anaerobic development is necessary for all distance runners. Thus, the physiological adaptation of the anaerobic energy system to race fitness in distance runners is chiefly directed toward both increasing the amount of stored buffering agents, and in increasing cell drainage of hydrogen ions, thus improving a runner's LLR. These adaptations all need to be done without damage to mitochondria. Frequently prescribed training sessions slightly above LT pace, at LT pace, and just below LT pace are an effective stimulus for these adaptations.

Despite the efforts of many, no source of supplemental sodium bicarbonate that the body will absorb has been found. The increased stores of the sodium bicarbonate buffering agent found in distance runners must be earned. Physiologists have shown that it takes about 9-12 weeks of sea-level training at LT pace and faster to fully develop the sodium bicarbonate stores. Curiously, physiologists have also found that sodium bicarbonate does not store well in muscle tissue at altitudes above 5000 feet. This may explain why $VO_{2\ max}$ decreases by 3% in response to every 1500 meters above this altitude. $VO_{2\ max}$ is a measure of aerobic power and is defined in most protocols as the effort to run two miles to exhaustion. This task is known to be an exercise completed at a mixture of 87% aerobically supplied energy and 13% anaerobically supplied energy to attain proper velocity. The decrease in aerobic power seen at altitude probably results from the compromised anaerobic contribution due to low sodium bicarbonate stores.

Training studies that were done both at altitude and sea-level in the late 1990s on distance runners by scientists James Stray-Gunderson Ph.D., and Benjamin Levine Ph.D., found that the most effective training protocol for athletes in the 1500-10,000 meter event range was to "live high and train low". By living high 20 hours per day at 7000 feet (i.e. Park City, Utah), the runners adapted to normal life at altitude. They increased their blood plasma volume, hematocrit ratio, erythrocyte, myoglobin, and hemoglobin mass. Through angiogenesis, they increased their capillary beds and enlarged the left ventricle of their heart. All of these adaptations made them better distance runners on the aerobic energy side. However, they did not increase their sodium bicarbonate stores, which were not stimulated by the effects of altitude.

For light to strong anaerobic training stimuli, including longer LT and tempo runs, the athletes in the altitude training study ran some days on a track or on the roads at a low altitude (i.e. Salt Lake City, Utah) which was convenient to where they lived. They did their long runs at high altitude where they actually lived. By doing LT runs and other anaerobic training at an altitude of 3800 feet, they did increase their sodium bicarbonate stores over the control group that trained exclusively at 7000 feet. The low training group became faster at their individual LT and did not lose $VO_{2\ max}$. The live high, train low, protocol has become the accepted training regime for many world-class distance runners.

The $VO_{2\ max}$ system of a runner improves dramatically during high school years, due to both specific event distance training, and growth and development of the person. Distance racing times drop drastically to match what is happening to the body. Eventually, the runner matures and $VO_{2\ max}$ development slows and even plateaus, despite frequent dosages of properly paced training. It has been proven over and over that just continuing to stimulate the runner with once a week $vVO_{2\ max}$ and occasional LT paced work does not elicit a much further adaptive response. Also, when a high school runner moves on to college, a whole new array of longer events become an option. No longer are the distance events of high school, which are physiologically aligned with aerobic power, the only races available to run. Races beyond 5000 meters are more aligned with aerobic capacity than aerobic power, thus the development of body systems that adapt to $VO_{2\ sub\text{-}max}$ stimuli become more and more the training focus. In essence, while maintaining a high $VO_{2\ max}$, concurrent training stimuli are designed to fractionize "the max", to gain the skill of running longer distances as close to $vVO_{2\ max}$ as possible. This is done through a heavy emphasis on LT pace work.

Let's look at an example. Rob is a 20 year-old college sophomore with a training age of six. He has moved up to the 10,000 meters in college, loves cross country, and wants to try to qualify for the Olympic Trials someday in the 10k or the marathon. Rob has asked his college coach to continue advising him all the way through these goals which will take many years.

Where does his coach begin? Since all training needs to be science-based, the coach should start there. For the first step, design a data table that shows where Rob currently is for key physiological markers, and then project it to where he needs to be at the end. This table could show many different physiological traits, characteristics, or distinctions, but it must clearly indicate the one vital piece of physiological development that will direct much of the focus of his long-term training to reach his goals. Table 2 projects Rob's reasonable future development for $VO_{2\ max}$ and $VO_{2\ LT}$ from a lab tested baseline at age 20. Rob was tested in a physiology lab at age 20 for both $VO_{2\ max}$ and $VO_{2\ LT}$. These are two common data sets obtained from an incline treadmill test to exhaustion. The standard measurement units used for these tests are milliliters of oxygen per kilogram of body mass per minute. The $VO_{2\ max}$ value for an untrained human is around 36 ml/kg/min and the highest value ever recorded was 96.7 ml/kg/min in a fit Nordic skier. The $VO_{2\ LT}$ value, which measures oxygen consumption at LT pace, is around 25 ml/kg/min in untrained humans. Rob's oxygen consumption values at age 20 for both $VO_{2\ max}$ and $VO_{2\ LT}$ are quite high, indicating a favorable genome to endurance activities, a previous training plan that was aerobicaly effective, and a high degree of cardiovascular system maturity.

Age	Projected $VO_{2\ max}$ (ml/kg/min)	Projected improvement	Projected $VO_{2\ LT\ (sub\text{-}max)}$ (ml/kg/min)	Projected improvement	Percentage of $VO_{2\ LT}$ to $VO_{2\ max}$
20	tested 72.8		tested 61.2		tested 84%
22	74.0	1.8%	63.0	3.0%	85%
24	75.5	1.8%	64.0	4.5%	85%
26	76.6	1.4%	67.0	4.5%	87.5%
28	77.5	1.3%	70.0	4.3%	90%
30	78.4	1.1%	72.0	3.8%	90.5%

Table 2. Shown is a long-term physiological developmental plan for Rob, an emerging long distance runner. The trend toward increasingly higher $VO_{2\ LT}/VO_{2\ max}$ percentages are in response to age and a switch in Rob's work emphasis.

Rob's coach knows to emphasize aerobic capacity training over aerobic power training from ages 21-30 for longer distance runners. Rob's $VO_{2\ max}$ development is pretty well mature by age 21, but his aerobic capacity capabilities have further potential for development. The switch from aerobic power work sessions to greater aerobic capacity work will push Rob to faster paces over the longer distances while delaying race-pace fatigue. If the projections from table 2 hold, Rob will be just a little faster over two miles at age 30 than he was at 21, but he will be considerably faster over 10k to the marathon at age 30 than he was at 21.

There are many physiological adaptations beyond a greater tolerance and drainage of hydrogen ions that contribute to an LT pace closer to the $vVO_{2\,max}$, or a quicker pace at LT for a runner. These include an increase in the quantity of many aerobic and anaerobic enzymes, improved inter-cellular storage of glycogen in muscles, greater dependence of the lactate shuttle, an increased cross-sectional diameter of Type 2a muscle fibers making them more fatigue resistant, and a better collective running economy. These all add up to higher aerobic capacity which is necessary for longer track events, road races, and the marathon. Let's look at a trio of specific case studies, all with different athlete profiles, and then prescribe means to implement various LT training schemes in each example.

1. Jason is a 21 year old junior in a successful collegiate program. His athlete profile for 5000 meter personal bests notes 14:35 as a freshman and 14:21 as a sophomore. His desire is to compete in 10 kilometer championship races over the remaining two years of school. In high school, his best marks were 4:14 for the 1600 meters and 9:15 for the 3200 meters. Jason's improvement has slowed a bit as he has gotten older and the chances of running sub 14:00 in college have dimmed. Let's diagnose Jason and look at specific training. Jason has spent his career stimulating adaptation to his $VO_{2\,max}$ system and it has reached developmental maturity. So, despite continued workouts at $vVO_{2\,max}$ pace, it is not going to improve much more. In moving to frequent LT work sessions, Jason will not only shift to an aerobic capacity emphasis to perform well at 10k, but his 5k time may drop as well; probably lower than it ever would have with just continued $vVO_{2\,max}$ paced work. During each week of training, Jason should do a long run with frequent surges that accounts for 22% of his weekly volume, a tempo run of five miles at 86% of his $vVO_{2\,max}$, and a critical velocity (CV) pace workout. The rest of the week is basically recovery runs at the aerobic threshold. A typical CV work session for Jason would be 4 x 2000 meters at 90% of $vVO_{2\,max}$ with two minutes recovery between repeats. Follow this unit with five minutes rest and then do 3 x 200 meters at 800 meter pace with 90 seconds recovery between repeats.
2. Alicia is a collegiate sophomore and she loves running the 5k. Alicia wants to continue in that event, but has plateaued-out in performance and has run five races right around 16:00 over the last two months. Despite her 5k woes, Alicia's 3200 meter time is at a career best and she is handling 65 miles a week of training just fine. Let's diagnose Alicia and look at specific training. Alicia appears to have chronic enzyme fatigue. The stimulus type and level in her training have been too repetitive and she is moving into a form of overtraining syndrome. Taking a month off of running would probably hit the proper re-set on her enzymes, but that is not desirable. Let's just change the stimulus for a couple of months with an emphasis more on aerobic capacity and less on aerobic power. Alicia should do two interval style LT sessions each week for a total of 16 sessions over the next two months. Each LT session will have three variables to consider: distance, recovery, and pace. For distance, Alicia should do four sessions at 400 meters, four sessions at 800 meters, and eight sessions at 1000 meters. For recovery, Alicia should do four sessions at 60 seconds, four sessions at 75 seconds, and eight sessions at 90 seconds recovery. For pace, Alicia should do four sessions at 85%

$vVO_{2\,max}$, four sessions at 87% $vVO_{2\,max}$, and eight sessions at 89% $vVO_{2\,max}$. Mix and match the three variables into work units that make sense for that day; for example, do not match up the longest distance with the shortest recovery and the highest intensity without understanding the load and consequences.

3. Marcus is a college senior and is a solid 5k and 10k runner. His junior year personal bests were 14:19 for 5k and 30:16 for 10k. He is 8:56 indoors for two miles. He wants to get the most out of his outdoor senior year, and his ultimate goal is to run under 30:00 for 10k. Let's diagnose Marcus and look at specific training. Marcus has few holes in his development, and his numbers align well for aerobic power and aerobic capacity performances. Marcus needs to spend April and May doing 1k repeats on his favorite trail course or the track. He will be doing lots of them, a dozen per week, spread between two work sessions. Each Monday, Marcus will do 5 x 1k at 90% of his $vVO_{2\,max}$ with 2:00 recovery between each repeat in April, and 1:30 between each in May. Following that unit each Monday, recover five minutes, then do 5 x 200 meters at 800-meter pace with 1:00 recovery between each repeat. Each Thursday, Marcus will do 7 x 1k at 87% of his $vVO_{2\,max}$ with 1:00 recovery between each repeat in April, and 45 seconds between each in May. Following that unit each Thursday, recover five minutes, then do 4 x 300 meters at mile pace with 1:00 recovery between each repeat.

Lactate threshold runs can be emphasized in a number of applicable ways depending on the circumstances. The crux in prescribing LT work is first determining the extent of aerobic capacity stimuli that are appropriate to the event, and where the athlete is developmentally at the time.

Improving the aerobic energy system is not only about structural changes to mitochondria, capillaries, blood, heart size, and oxygen delivery. If it was just those things, then strictly mileage totals would decide distance race results. Improving the aerobic system is also about chemical changes to enzymes, buffering agents, myoglobin, hormones, and genetic signaling. Yes, these things too are stimulated to change by mileage, but adaptations found here are much more influenced by mileage in combination with intensity. Any distance coach can prescribe mileage, diagnosing intensity takes creativity in developing distance runners.

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