

Office Based Exercise Physiology

Ben Greenfield, MS , NSCA-CPT, CSCS



A. Exercise Physiology Lab Procedures

- LT
- AT
- VO₂
- RMR
- Sweat Sodium
- BF%
- Coaching
- Nutrition

B. LT/MLSS/Max Lac

- Definition
- Equipment
 - Lactate Pro
- Procedure
 - 4-5m Stages
 - Blood lactate stabilization
- Termination
 - 4.0 mmol
 - Rapid rise
 - RPE 8+ & ventilation increase
- Threshold vs. Max Lac.
 - Threshold=aerobic capacity
 - Max Lac=anaerobic capacity
- Interpretation
 - Depends on individual (polynomial, linear, etc.)
 - Curve shifts/importance of re-testing
- Run/bike/swim

C. LT Ironman Application

- Physiology of Ironman
 - Intensity
- Beginners:
 - 81-88% bike, 85-91% run
 - 15-30 beats below LT
- Intermediate/Advanced:
 - 89-93% bike, 92-95% run
 - 5-15 beats below LT

D. Why Train at % of LT?

- Different muscle fibers produce different forces while utilizing different fuels with different energy systems, different metabolic byproducts and different rates of fatigue.

E. 2 Basic Muscle Fiber Types

- Type I (Red Slow-Twitch)
 - Aerobic

- Fats/carbs/proteins as energy
- Less pyruvate/lactate production
- Low force + high time to fatigue
- Type II (White Fast-Twitch)
 - Anaerobic
 - Carbs as energy
 - Higher pyruvate/lactate production
 - High force + low time to fatigue
 - Type IIB to Type I Conversion

F. 3 Basic Energy Systems

- Oxidative (slow-twitch)
 - Aerobic
 - O₂ to H₂O + ATP (energy)
 - Fat, proteins, carbs
 - Kreb's cycle
 - 2+ minutes
- Glycolytic (fast-twitch)
 - Anaerobic
 - Glycolysis
 - Glucose to lactic acid + ATP (energy)
 - 30-60 seconds
- Phosphagenic (fast-twitch)
 - Anaerobic
 - Creatine to ATP (energy)
 - <15 seconds

G. Training/Racing Zones Based on Energy System/Fiber Type

- Quantified
 - 75-80% (recovery)/RPE 3-4
 1. Oxidative
 2. Slow Twitch
 - 81-84 (long endurance)/5-6 (1.0mmol + baseline)
 1. Oxidative
 2. Slow Twitch
 - 85-93 (muscular endurance)/6-7
 1. Oxidative/Glycolytic
 2. Slow Twitch/Fast Twitch
 - 96-99 (below threshold)/8-9 (4mmol/sharp rise)
 1. Oxidative Glycolytic
 2. Slow Twitch/Fast Twitch
 - 100-106 (above threshold)/9-10
 1. Glycolytic/Phosphagenic
 2. Fast Twitch
 - 107+ (speed/power)/10
 1. Phosphagenic
 2. Fast Twitch

H. Why Train in "Zones"?

- Control energy system use

- Ironman specific
 - Increase oxidative capacity
 - Increase fat and lactate utilization (slow twitch)
 - Decrease lactate production (fast twitch)
 - Increase glycogen conservation
 - H⁺/ammonia limitation + recovery
 - Increase time to respiratory fatigue
- Training effect specific
 - Aerobic training/anaerobic detraining
 - Increase LT HR as % of VO₂ HR
- Periodize/structure training
 - Recovery implications above/below LT
- Specific focus to training period
- Variable Quantifiers
 - Power, MHR, LHR, RPE, VO₂

I. AT

- LT difference
 - Blood vs. CO₂
- Equipment
 - Spirometry
- Procedure
 - VCO₂ vs. VO₂
 - Disproportionate RER rise
 - Lowest point VE/VO₂
 - Lowest point PETO₂
- Ironman application: same as LT, less accurate

J. VO₂

- Equipment
 - Spirometry
- Procedure
 - Lactate/VO₂ protocol
 1. 1m increments after reaching LT
 - Bruce
 1. 3m stages
- Termination
 - Exhaustion
 - RER=1.10+
 - VO₂ plateau
- Interpretation
 - ml/kg/min or L/min
 - Relative vs. absolute

K. VO₂ Application

- Track *Potential*
- CO * a-t O₂ diff
- Internal utilization system
 - Mitochondria
 - Greater limitation in untrained (insufficient oxidative capacity)
- External delivery system

- Heart & Lungs
 - Greater limitation in trained (must maintain central pressure)
- Trainable?
- $VO_2 \cdot LT = \text{engine size}$
- Efficiency matters
 - Ferrari vs. Ford – efficiency of engine depends on chassis

L. Other Respirometer Measurements

- RMR
 - Baseline fueling
 - Weight loss/gain
 - Pre-race meal?
- RER
 - Work potential
- FEO₂
 - Muscular O₂ utilization
- VE/VO₂
 - Ventilatory efficiency
- Caloric Utilization!
 - O₂=total calories
 - CO₂=carb oxidation

M. Predict Utilization From VO₂ max

- 30-40% of oxidation or loss

N. Ironman Fuel

- Carbohydrate
 - Oxidation rate 60-80g/hr
 - Storage 1500-2500 kcal
 - Loading possible up to 20%
 - Source – complex vs. simple
- Fat
 - 60% energy source at 3+ hr
 - MCT's
- Protein
 - 30% energy source at 3+ hr
 - BCAA's
 - Whey vs. soy
- H₂O
 - Capacity avg. 17-25oz/hr
 - Hyponatremia
- Electrolytes
 - Sodium, chloride, chromium, potassium, calcium
 - Storage 8000mg/loss varies

References:

Katch, FI and Mcardle WD (1996) Energy, Nutrition and Human Performance (4th ed). Balitmore, Maryland: Williams & Wilkins

Noakes T.D. Lore of Running. Leisure Press. Champaign Illinois. Pages 768-770 29 published and unpublished papers cited on fuels, fluids, electrolyte issues during endurance exercise.



CHAMPIONS SPORTS MEDICINE

www.champsportsmed.com

Champion Sports Medicine Blood Lactate/VO2 Results

Joe Triathlete – Exercise Metabolic/Blood Lactate Results

Lactate	HR	Watts	RPE		
2.4		46	0	0	
1.3		98	50	2	
1.5		100	100	2-3	
1.5		106	150	4	
1.9		119	200	5	
1.7		131	250	5-6	
3.1		144	300	7	
6.8		156	350	8-9	
Bike LHR	Training Zones	Bike Low HR	Bike High HR	Run Low HR	Run High HR
147	1 recovery	96	118	116	123
Run LHR	2 long endurance	119	123	124	129
154	3 muscular endurance	124	134	130	143
VO2Max HR	4 low threshold	135	146	144	152
195	4 high threshold	147	150	154	157
LHR%	5 sustained speed	151	162	158	169
75	6 power	163	176	170	185
LHR Watts	Zones	Low Watts	High Watts		
280	1 recovery	112	154		
Max Watts	2 long endurance	155	210		
400	3 muscular endurance	211	252		
LHR%	4 low threshold	253	279		
70	4 high threshold	280	308		
	5 sustained speed	309	392		
	6 power	393	559		

The following discussion should help you to understand your result. For a more detailed explanation, or personal coaching, please contact Ben Greenfield at elite@pacificfit.net.

DISCUSSION OF RESULTS – Joe Triathlete

LHR on the bike, as a percentage of approximate VO2 HR, is at 75%. This number, through proper lactate threshold training, can be elevated a range in the upper 80's to lower 90's percentile. Based on your relatively high VO2 max (68.9ml/kg/min), I recommend your focus should be on training to improve LT, with a lesser emphasis on VO2 max. The former can be achieved by training with longer intervals (8-20 minutes) in Zone 4 low threshold and shorter intervals (3-7 minutes) in Zone 4 high threshold. The longer intervals can employ at 3:1 or 4:1 work:rest ratio, and the shorter intervals a 2:1 work:rest ratio. I recommend one LT interval training session per sport per week, with a focus on shorter intervals at higher % of LT as the high priority races approach. Only 1 session per week should be devoted to VO2 max work, utilizing 1-2 minute intervals in heart rate zones 5-6, and a 1:2-1:4 work:rest ratio.

Overall wattage could also be improved due to this season's A priority race taking place on a course with over 12 steep rolling hills. By increasing force capacity and efficiency of muscular contractions while climbing, you can increase your LHR as a % of maximum wattage. I recommend shorter 2-4 minute hill climbing sessions with a focus on low RPM and force application, as well as "stomp" workouts on the flats (high gear, low RPM). Unilateral pedaling and superfast spin drills would also assist with force application. For your actual race, you will be focusing on maintaining HR in high zone 3, low zone 4 for both the hills and flats.

Contact me with any questions...

Ben

LACTATE HEART-RATE TRAINING ZONES

Zone	LHR	Description
Zone 1 Level: Endurance, Recovery System: Oxidative	65-78%	After hard workouts, very easy workouts accelerate recovery more than complete rest. Easy aerobic training stimulates circulation, which accelerates tissue healing response. Intensity is enough to increase blood circulation and trigger a growth hormone response, but not intense enough to cause significant muscle damage. This effort range is also used during long endurance efforts (over 60 minutes), in which it can be more fatiguing due to energy and fluid depletion.
Zone 2 Level: Endurance System: Oxidative	79-84%	This zone will also feel very easy (“conversational” effort). Training at this intensity primarily uses slow-twitch muscle fibers, since these fibers provide more most of the mobility for events lasting 2 minutes or longer, workouts at this intensity should comprise most of your training. Training above this intensity will not significantly overload your slow-twitch fibers, which you are attempting to train to become more efficient at using oxygen to produce energy while conserving carbohydrate stores. This intensity is important for training the body to use fat as a fuel, especially for individuals who compete in events lasting more than two hours. Although it will be difficult to keep your intensity low on these days, performing your endurance efforts at a higher intensity than Zone 2 will reduce the effectiveness of your harder workouts on subsequent days by fatiguing muscle and depleting carbohydrate stores in fast-twitch muscle. This can lead to overtraining.
Zone 3 Level: Muscular Endurance below AT System: Oxidative Glycolytic	85-90%	During an endurance workout, your intensity may reach this level on hills. The body is still primarily functioning aerobically, conversation is possible, and burning in the legs/shortness of breath is minimal. However, the intensity is too high for maximal stimulation of the slow-twitch muscle fibers and fat-burning. As intensity increases from zone 2 to zone 3, oxygen debt becomes greater, and since it takes more oxygen to burn one calorie from fat than from carbohydrate, more carbohydrate and less fat will be burned. At zone 3, you are not performing at an ideal intensity to make yourself faster, and you are depleting your carbohydrate stores for the next day’s workout. However, if your lactate threshold is low, you should perform intervals, hills climbs, and race pace training in this zone. Otherwise, spend the least amount of time at zone 3.

<p>Zone 4 Level: Muscular Endurance at AT System: Oxidative Glycolytic</p>	<p>91-102%</p>	<p>Lactate threshold (LT), also called anaerobic threshold (AT), is the highest intensity at which the body can recycle lactic acid as quickly as it is produced. In zone 4, the aerobic and anaerobic systems are working together in balance to provide energy for exercise. Anaerobic metabolism is slow enough that lactic acid, the substance that makes muscles burn during hard exercise, does not accumulate. At this intensity, you are working very hard, but can still maintain exercise because lactic acid levels in the blood and muscles are steady, not increasing. Increasing the intensity just slightly causes lactic acid to build up and brings premature fatigue and delayed recovery. Training near lactate threshold decreases the amount of lactic acid being produced and increases lactate removal at a given output. At this intensity, the fast-twitch fibers can be trained to produce less lactic acid and the slow twitch fibers can be trained to burn more lactic acid, both of which raise the lactic acid threshold and allow you to work harder at a higher intensity. Since lactic acid levels are controlled, recovery from this type of training is quicker than from other high-intensity training methods, therefore zone 4 training has the best cost:benefit ratio of any type of training. When you experience “rubbery leg” syndrome, a marked increase in breathing difficulty, you have reached the point where lactic acid accumulates at a faster rate than it can be removed, which will rapidly decrease your ability to maintain a steady effort, and take you into Zone 5.</p>
<p>Zone 5 Level: Sustained speed System: Glycolytic, Phosphagenic</p>	<p>102-110%</p>	<p>Intensity now exceeds the lactate threshold and the body is stressed in its ability to withstand high lactate levels and remove lactate. In Zone 5, lactic acid builds up quickly, so this intensity cannot be sustained for long periods. This intensity is anaerobic, so your body cannot use oxygen, which limits efforts in this zone to about 60 seconds maximum. Zone 5 training is a very effective means of increasing speed and performance, but because lactic acid levels become extremely high, this type of training requires extensive recovery between both workouts and intervals. Zone 5 training is beneficial, but should not be overdone. In addition to increasing an athlete’s sprint power, training at this intensity will improve an athlete’s economy, or efficiency. High levels of training in this zone is another common cause of overtraining. Typically, the only work done in this zone is interval training and hill repeats.</p>
<p>Zone 6 Level: Explosive speed System: Phosphagenic</p>	<p>111-max%</p>	<p>This intensity can only be maintained for up to approximately 15 seconds. Athletes who need development in the fast-twitch muscles, explosive power, or improvement in running mechanics should train at this level. These type of workouts are typified by short, explosive intervals followed by long recoveries. Every athlete should take this kind of training seriously, because it can take over 48 hours to recover from a medium to high repetition workout in this zone.</p>

Triathlon Training Abilities, Periods of Training Cycle, and Sample Workouts			
Ability:	Period:	Run/Bike Workouts	Swim Workouts
Recovery	All periods	Long and slow, 20-30 min	Long and slow, 20-30 min
Endurance – slow twitch	Zone 1, 2 Base A, B, C	Long and slow, 60 min+	Long and slow, 60 min+
Muscular Endurance (below anaerobic threshold) – slow twitch/fast twitch mix	Zone 3 Base A, B, C	Tempo Runs, Long Hills at Moderate Pace, Medium Intensity Interval Repeats, Medium Intensity Track Intervals (running), Surge Intervals	Tempo Swims, Cruise, Medium Intensity Interval Repeats, Surge Intervals
Muscular Endurance (at anaerobic threshold) – slow twitch/fast twitch mix	Zone 4 Base B, C Build A, B Peak Race	Tempo Runs, Long Hills at Moderate Pace, High Intensity Interval Repeats, High Intensity Track Intervals (running), Surge Intervals	Tempo Swims, Cruise, High Intensity Interval Repeats, Surge Intervals
Sustained Speed – oxygen dependent/independent fast twitch	Zone 5 Build B, C Peak Race	Long Hills, Longer Sprints	Longer Sprints
Explosive Speed – oxygen independent fast twitch	Zone 6 Build A, B Peak Race	Short Hills, Shorter Sprints, Plyometrics, Short Speed Bursts	Shorter Sprints
Skill	Zone varies. Base A, B, C Build A, B Peak Race	Downhill Repeats, Cadence Counts, Isolated Leg, Agility/Power Drills, Fast Spins	Stroke Counts, Speed/Agility/Power Drills, Paddles, Drag, Open Water
Race Pace	Build A, B Peak Race	Time Trials, Races	Time Trials, Races (open water especially)