Performance Conditioning Cycling 20th Anniversary Issue

This issue is dedicated to the memory of Ed Burke our first Senior Editor and driving force in the creation of this publication. We also wish to thank USA Cycling for their past and continued support in our efforts to educate cycling coaches through this publication. Thanks to Kevin Dessart, USA Cycling Director of Coaching Education and Development, Jim Miller USA Cycling VP Athletics and Steve Johnson, CEO, USA Cycling.

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When it comes to cycling performance does pedaling technique really matter?

Of course it does. To say otherwise is like saying that cycling is the only sport in the world where the technique of the major component of the sport doesn’t matter. But this myth persists. It persists simply because pedaling technique has been almost imposible to measure (requiring expensive pressure plate pedals generally available only in university research labs) and pedaling technique is almost impossible to change making it “impossible” to study. *If something is hard to measure and even harder to change it is easy to conclude it doesn’t matter.*

So, what is the optimum pedaling technique?

Now, there may be many different techniques possible and no one knows for sure exactly what is optimum but the one technique that many coaches talk about as being “optimum” is “pedaling in circles”. But, what does “pedaling in circles” mean? It does not mean applying equal pressure around the entire circle, as is thought by many, as equal pressure around the circle is impossible because of the effects of gravity. What “pedaling in circles” really means is spreading the work out around more of the circle and doing no negative work on the upstroke — increasing the power at the top and bottom of the stroke and minimizing or eliminating the losses on the upstroke. Such a technique is exactly the technique Lance Armstrong has been trying to perfect since 1993, see: [www.powercranks.com/Lance.html](http://www.powercranks.com/Lance.html). There is now a tool (PowerCranks, Walnut Creek, CA - [www.powercranks.com](http://www.powercranks.com)) that can teach this technique to your clients so you can concentrate on other things. Not a gimmick, a serious training tool actually used by the last three Olympic road race champions and many other Olympic, World, and National champions in a wide variety of cycling disciplines including track, cyclocross, mountain biking, and triathlon. You may not have heard about this use as it is a training tool and easily kept from others. Why would an athlete want to share an advantage with the competition?

What are the advantages of pedaling using this “full circle” pedaling technique?

1. It uses more muscle mass, increasing peak power potential.
2. It distributes the work around more of the pedal circle which means using more muscles, allowing any one muscle to be further away from its lactic threshold for any given power.
3. These changes together have the potential to greatly improve both pedaling efficiency¹, VO₂max² and sustainable power. Many studies support this approach.³

See the diagrams comparing actual pedaling forces changes seen in a single rider between regular cranks and PowerCranks. It is clear these are relatively small and subtle changes but these small changes in the direction of the applied force results in large changes in the resultant power to the wheel for any given muscular effort. **Note that when on PowerCranks the negative forces are completely eliminated and the forces across the top and bottom of the stroke are substantially larger over regular cranks. With these changes this rider is actually “pushing” less hard to generate the same power despite the fact he is riding at a lower cadence.** Can there be any doubt that as the rider changes their natural way of pedaling to this more efficient and powerful technique that performance will improve?

In the past (before PowerCranks) coaches and riders didn’t have to worry too much about pedaling technique because it was pretty much impossible to know how a rider was actually pedaling (you needed pressure plate pedals, only available in the research lab) and, even if you got that information there were not any good tools to effectively change pedaling technique. Ignorance was bliss. But, this is about to change with the soon-to-be-released Metrigear Vector pedal (see: [www.metrigear.com/products/](http://www.metrigear.com/products/)). Soon, pedal force data will be affordable and available to everyone and your clients are going to be asking you for advice as to how to improve this aspect of their game. Better start planning how you are going to approach this now. Such changes do not come easily. You can set your clients on the 17 year path taken by Lance Armstrong or you can set them on the 6-9 month path allowed by integrating PowerCranks into their training. What are you going to choose? There is simply no more effective way than PowerCranks to effect this change.

In the near future, if you ignore this aspect of the cycling game we predict you will be seen by your ex-clients as “old fashioned” and “irrelevant”. Prepare now. PowerCranks will help you teach this skill to your clients with maximum efficiency and if you become an associate, we can even help out your bottom line. Check us out, [www.powercranks.com](http://www.powercranks.com) • 888-733-2572

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¹,²,³ studies that show cycling efficiency improvement, VO₂max improvement in trained cyclists, and many other studies related to pedaling technique (including those studies that many say “prove” that pedaling technique doesn’t matter) are available here: [www.powercranks.com/studies.html](http://www.powercranks.com/studies.html)
On the positive side, coaching has become a legitimate profession, with certification and better pay scales. That the average person seeks coaching and can get it, is transformative. However, a few things bother me about this access. The move to long-distance coaching via email is not providing full service. I have observed too many athletes who are coached this way are missing major links - like good bike position and riding skills. The lack of riding skills in group rides today is appalling. I fault the emphasis on training, rather than on developing the whole rider, for this demise.

- Peg Maass-Labiuk

A Look at the Evolution of Cycling Conditioning and Coaching

What Coaches Think

We asked several cycling coaches to answer the following question: "In the last 20 years how has the profession of cycling coaching evolved?"

Here what they say:

In the last 20 years cycling has changed from being the least data-driven of the popular endurance sports to the most data-driven. This is largely due to the power meter. As a result coaching has become considerably more scientific. Today's coaches are much more knowledgeable in every aspect of training, not only power, but also in other scientific disciplines such as physiology, psychology, nutrition, and more. Coaching is no longer a "best guess," "seat of the pants" activity as it was 20 years ago. The bottom line is that coaching has changed dramatically in 20 years. It's a true "profession" now.

- Joe Friel, Father of Cycling Periodization

On the positive side, coaching has become a legitimate profession, with certification and better pay scales. That the average person seeks coaching and can get it, is transformative. However, a few things bother me about this access. The move to long-distance coaching via email is not providing full service. I have observed too many athletes who are coached this way are missing major links - like good bike position and riding skills. The lack of riding skills in group rides today is appalling. I fault the emphasis on training, rather than on developing the whole rider, for this demise.

- Peg Maass-Labiuk

When I think about this question, three words come to mind: technology, power and metrics. Obviously, technology has had a massive impact on our sport. Not only can that technology be found on bikes, it can be found in cycling kits, shoes, socks, gloves, helmets, eyewear, pedals and bike tools. However, the most significant impact of technology may be found in the power meter and the wealth of information it provides for cyclists and coaches alike. 20 years ago, terms such as functional threshold power, normalized power, kilojoule, variability index, efficiency factor and intensity factor were not yet part of the cycling lexicon. Today, we routinely apply these concepts in ways that significantly impact cycling performance. Something that’s been made possible with the tremendous advances in technology we have seen over the past two decades.

- Dr. Tyrone A. Holmes, Ed.D, CPT, Holmes Fitness Coaching, LLC-USA Cycling Level I Coach

Symbols to Success

Articles preceded by BGN indicates author believes content is for beginning-level athletes with training age of 0 to 2 years.

INT indicates author believes content is for sport (intermediate)-level athletes with training age of 2 to 4 years.

XTP indicates author believes content is for expert-level athletes with training age of over 4 years.

MSR indicates author believes content is for master-level athletes over 30 years of age.

MTB indicates author believes content is for mountain biking.

NOTE: Training age year is continuous year-round conditioning.

R following articles indicates the content has been reviewed by the editorial board.

D following articles indicates the content is the sole opinion of the author.

Official Licensed Publication of the USA Cycling Coaches Association
I remarked in our last column that training and coaching has moved into the “Age of Technology”. Technology has made a huge impact to our coaching profession. The technology explosion began with the individual’s wireless heart rate monitor, training zone definitions for workout intensities, and electronic training logs. This beginning evolved into power training, uploading workout files, electronic calendars, and electronic training charts. These advancements have expanded the understanding of our athletes’ conditioning beyond imagination. It has accelerated the scope of our knowledge such that we can confidently guide our athletes to maximize their performances in alignment with important events. Technology allows coaches to get speedy, if not “real-time”, feedback that wasn’t dreamed of 20 years ago.

It’s not just the charts and metrics produced by training software, other technology advancements have helped coaches improve their coaching. As an example, subsequent to my recent hip surgery, I’ve used Skype to direct indoor practices for our team. Although confined to my family room coach, I’m able to conduct practices without missing a beat. Additionally, I’ll “join” the team on training rides using Garmin’s “Live Activity”. Simply said, coaching has become a “Trekkies” delight. - Ralph Frazier, Frazier Cycling

In the past 20 years (I feel), the two biggest changes in cycling coaching is technology and the practices of recovery. Internet and coaching technology have changed the way we can help athletes all over the world. The use of different types of technology has greatly improved how much data we can obtain and use to help our athletes achieve their goals. There are many self analysis products coming out on the market, as well as affordable power meters that make training and coaching more accurate. All of these innovations in science and technology help us track training progressions and help us reiterate the importance of recovery as another tool in training. - Michelle Grainger, USAC Level 1 Certified Coach, USAC Certified MTB & CX Coach

Over the 35 years of my coaching career, it’s been exciting to have been a part of the developments of the last 20 allowing the avocation to become a vocation. Certainly, technology has been at the heart of this shift; scientific performance devices formerly confined to the laboratory are available, not only to coaches, but all levels of athletes AND the internet to exchange data/communicate in real time. The power meter has removed the estimating of lactate threshold and provided a “diamond cut” for specificity of training. The intricacies of nutrition for performance and recovery are common knowledge and has its monitoring software is available to all. Indeed, technology has brought the “science” of cycling and its coaching to the “common man.” On the flip side, in the midst of all this proliferation of knowledge, I see the “art” of coaching becoming it’s “little sister” rather than its former tandem partner. Yes, the technology secures the scientific foundation of the training program to solid ground, however, it can never replace the wisdom and intuition that creatively brings the program to the person. - Marilyn Trout, USA Cycling Certified Elite Coach, National Coaching Certification Program – Level 3 (Canada), World Road Race Championship

Over the past 20 years, professional cycling coaching not only evolved, it was established. Coaching existed prior to this, but it wasn’t thought of as a profession. Almost no one got paid for coaching cyclists, except national team coaches. Experienced cyclists helped mentor new cyclists. When I started racing in 1973, our club had a self-appointed coach named Joe Tosi. He was good at mentoring but it wasn’t a formal relationship and he certainly didn’t have any coaching training or certification. It wasn’t until Joe Friel and Chris Carmichael started coaching and publicizing coaching that it started to become a legitimate profession. Joe Friel wrote the “Cyclists Training Bible” in 1996 and this formalized the concepts of cycling coaching and made it available broadly. Reading this book got me thinking about coaching and I immediately started following his principals in my own self-coached training program. In 2001, I learned about USA Cycling’s coaching licensing program and I became a certified “Sport Coach” shortly after. Chris Carmichael’s widely publicized coaching of Lance Armstrong brought professional coaching to a new level in the early 90’s, concurrent with Lance’s notoriety. The ranks of coaches licensed under USA Cycling has mushroomed since this time and now many coaching are full time professionally. It is now a recognized profession, at least within the cycling community. - David Ertl, USA Cycling Level 1 Coach

Every aspect of Cycling Coaching has grown exponentially in the last 20 years. “Coaching”, once reserved for elite athletes or teams, is now accessible to riders of all levels, and there are coaching packages available to fit any budget. There are many more athletes seeking training programs, and more coaches to meet the increased demand. The advent of the Internet made delivering “remote coaching” much easier. Remember when training programs had to be “faxed” to athletes? Just as heart rate monitors were once very exotic & elitist, power meters have gone from being a luxury to being very accessible to all athletes. Monitoring athlete performance with a power meter has been the biggest change in how we coach cyclists. Power meters have made it much easier to analyze training and racing efforts, and to quantify athlete performance. ANT+, Bluetooth and GPS devices have contributed to providing more details about workouts or races, and allow this information to be shared in real time. Social media sites and websites like Strava give riders and coaches global access to information and create a way to compete “virtually” against riders anywhere in the world. Coaching has evolved from a mystical craft based on traditions and old-school mantras to a business driven by technology, data and advances in equipment. All these innovations give coaches more tools to help athletes, but what makes a coach successful is still the coach’s ability to take the information, design realistic workouts for the athlete and provide motivation and support to help the athlete reach their goals. - Ann Marie Miller, Level 2 USA Cycling Licensed Coach-Category 1 racer

Now Let's Look Back 20 Years Ago!
Periodization: Planning Your Comprehensive Training Program

WHAT YOU NEED TO KNOW FIRST

Roger Young

This is the foundation of the coaching profession -- periodization. Periodization is a method for structuring a training program into well-integrated phases of work and recovery. It allows coaches to break down a larger program into smaller, more manageable units in order to plan for proper peaking and avoid overtraining. — Originally published in Performance Conditioning for Cycling Volume 1 #1

Periodization: An Overview

Coaches consider a training schedule to be a plan that, when executed properly, will bring about the best performance an individual is genetically capable of achieving. This is the foundation of the coaching profession -- planning comprehensive training programs. Periodization is a method for structuring a training program into well-integrated phases of work and recovery. It allows coaches to break down a larger program into smaller, more manageable units in order to plan for proper peaking and avoid overtraining.

Macrocycles - The Big Picture

Prior to designing a training program for a cyclist a coach should examine what part of his or her career a rider is in. This exercise establishes a unit of periodization known as a "macrocycle." Typically a macrocycle is a year in length, although it is not unusual for riders to have two year macrocycles while developing for particular World Championships. Four-year-long macrocycles are common for riders preparing for Olympic Games or career changes like going from amateur junior cyclist to professional.

Case in point: Jim Ochowicz and the 7-Eleven Team planned for two distinct macrocycles several years ago. The first was as an amateur team preparing for the 1984 Olympic Games (1981-1984); they then established a second macrocycle to develop them into a professional road team capable of riding in the Tour de France.

As a coach you need to be careful when deciding the length of a rider's macrocycles. The most common mistake is expecting to do too much in one year. Other problems will arise if you do not take into account logical transitions. A match sprinter, for example, will probably not be able to go straight into the training/racing volume of a professional road rider within one year. Keep in mind this big picture before you begin prescribing workouts.

To be able to plan your program you need to be familiar with the following periodization terms specific to cycling:

**STRESS:** Stress is calculated by adding up values for skill+intensity+volume (see Stress Table). Training itself is a matter of applying stress in an attempt to bring about some degree of adaptation (hopefully in a way that helps a rider to win more races!).

**FLOW PATTERN:** The relative level of "stress" defined in the training program as exhibited over time. A simple flow pattern for a training period could show a stair step graph as training does from "easy" to "moderate" to "hard" (See "stress table" for components of stress.)

**MACROCYCLE:** The largest unit of periodization, ranging in length from one year to several years. Typically the macrocycle is defined by what level of competition a cyclist wants to elevate to (or maintain).

**MESOCYCLE:** Also known as a training period, a mesocycle is a subdivision of a macrocycle. In other words, a macrocycle is made up of mesocycles. These units may be as short as one week or as long as the macrocycle which contains them. A mesocycle is usually defined by the physiological system being addressed or by seasonal concerns like "race season" or riding skills.

**MICROCYCLE:** These are subdivisions of a mesocycle. Usually one week in length, microcycles follow the flow pattern of a mesocycle. The flow pattern of a mesocycle is thus expressed by the relative stress levels of its microcycles.

**SESSIONS:** These are single training units that make up a microcycle. Training sessions are scheduled to achieve the prescribed level of stress for the microcycle, and to follow the flow pattern for that microcycle.

**WORK-OUT:** These are training activities that make up a training session. Often used synonymously with sessions (especially when there is a single activity in the session), work-outs are the building blocks of a training session. Coaches will customarily coordinate work-outs like hill sprints and endurance road rides into a single training session.

Testing - Measuring Your Progress

Testing is a crucial element in developing and adjusting a program of periodization. Initial testing will establish baseline values so that the coach has a starting point to work with. After the program is established the coach monitors the training and records training data. This regular monitoring and periodic testing should report how the athletes are responding to the training sessions, and allow the coach to adapt the program to the rider's needs.

Anomalies observed while monitoring training sessions require the coach to change the execution of the particular work-out -- the sooner the correction is made, the better. Chronic improper workout execution and other negative influences like injuries
It is important to develop a test that shows you the effectiveness of your training. This means that it needs to address those elements of performance which you are trying to improve. For example: During the base phase of a sprinter’s program, the coach wants to see how the sprinter’s rate of recovery between sprints improves. A typical test involves a series of sprints under similar conditions and measures how long it takes the rider to return to a resting pulse rate. If there is no improvement in recovery time and the work rider to return to a resting pulse rate. If there is no improvement in recovery time and the workouts have been executed correctly, then the coach will need to change the program, adding more endurance work or even extending the training period itself. To help you get started, we’ve designed a checklist for designing your training program (see Table 2). Use it as a handy reference as we provide you with step-by-step planning methods in future issues.

Table 1 - Cycling Stress Chart

<table>
<thead>
<tr>
<th>Skill</th>
<th>Intensity</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>35%</td>
<td>15%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Beginning Cyclists: For safety and development of efficiency, beginners should have a large amount of skills work factored into the stress levels of their training programs.

Intermediate Cyclists: Intermediate cyclists should have the largest volume component in their stress level.

Advanced Cyclists: Advanced cyclists should have the largest amount of intensity assigned.

When figuring the values for each of the three stress factors (skill/volume/intensity) use these equations:

**SKILL:**
- pedalling = 1 point
- balance = 1 point
- steering = 1 point
- maneuvering = 1 point
- tactics = 1 point
- max possible = 5 points

**INTENSITY:**
- heart-rate zone 0 = 0 points
- zone 1 = 1 point
- zone 2 = 2 points
- zone 3 = 3 points
- zone 4 = 4 points
- zone 5 = 5 points
- max possible = 5 points

**VOLUME:**
- < 30 minutes duration = 1 point
- 31 min - 1 hour = 1 point
- 1-2 hours = 1 point
- 2-4 hours = 1 point
- 4+ hours = 1 point
- max possible = 5 points

**MAXIMUM STRESS = 15 POINTS**

Table 2 - Training Program Design Checklist

I. OUTLINE THE RIDER'S CAREER
II. IDENTIFY THE MACROCYCLES
   1. Flag the primary event(s) of this year
   2. Flag the secondary event(s) of this year
   3. Identify the peaking and tapering periods
   4. Define the dates of the competition period
   5. Define the weeks of the preparation period
   6. Define the weeks of the transition period
III. DEFINE THE PRESENT MACROCYCLE
   1. Display the flow patterns for this year's mesocycles
IV. EXHIBIT THE MESOCYCLES FOR EACH TRAINING PERIOD
   1. Display the flow patterns for this year's mesocycles
V. EXHIBIT THE FLOW PATTERN FOR EACH MICROCYCLE
   1. Display the breakdown of each week's stress value into the relationship between intensity/volume/skill
   2. Assign volume/intensity/skill value to each day
   3. Note the work-outs that fulfill all of the above
VI. ASSIGN EACH DAY'S TRAINING SESSIONS
   1. Assemble work-outs that fulfill the specific volume/intensity/skill values for each session
Control of your training is critical to peak performance and maximization of time. Through the systematic use of a heart rate monitor, a cyclist can help his or her training progress more rapidly to a higher level. In many ways, training with an accurate heart-rate monitor is like having a full-time coach. As you train, your heart rate will be displayed on the monitor, which measures your cardiovascular and physiological stress during your training sessions and races. Your training log can now reflect an accurate level of intensity for an exercise session, regardless, of the training stimulus or outside stresses to your body. For the cyclist, a heart rate monitor can take the guess work out of training intensity and also serve as an excellent motivator for those days when you want to accurately evaluate your performance and adjust your training regimen.

Finding Your Maximum Heart Rate

In order to effectively use your monitor in training, you need to know your maximum heart rate. Many individuals use 220 minus your age to determine your max heart rate, but in trained individuals there may be a more accurate method of determination. Gary Hooker, past age class record holder in the Ironman (40-44 year old division in 10 hours and 19 minutes), uses the following tests. Your average heart rate during a 5 kilometer time trial will be approximately 95 percent of your max heart rate. Wear your heart rate monitor during the all-out paced effort of 5 kilometers (set to record at 5 second intervals if possible). Then plot the data, plotting heart rate vs. time. When you look at the data, in the mid-portion of the ride you will see that it levels out. Assign a proper heart rate to that level and multiply that number by 105 percent to estimate your max heart rate.

If you prefer to record your heart rate during a 10 kilometer time trial, your max heart rate will be about 93 percent. The procedure to follow is the same for the 5K time trial, but multiply your average heart rate by 107%.

Ways of Gaining Feedback from the Heart Rate Monitor

**Technique:** We spend a great deal of time working on our technique. For example, find a hill about one mile long. Mark the beginning and end of the section, so that you can time yourself and ride at the same pace during each trial. Ride the hill in your normal position and gearing and time yourself and watch your heart rate during the last half mile. Now set your monitor on the heart rate range that is slightly above and below your heart rate that was recorded during the last half mile of the first ride. Ride the section again with a different technique. Bigger or smaller gear, higher or lower cadence, in or out of the saddle and try to keep your heart rate in the same range. Time yourself. Through this, you will determine the most efficient technique during a hill climb (the fastest method for the same energy output). The same procedure can also be used for time trial training.

**Recovery:** Between intervals, the monitor will give you feedback concerning your recovery rates. Try to relax as you are recovering and even concentrate on being able to bring your pulse down. This can be important during a race.

**Before the Race:** Wear your monitor before some relatively important races. Wear it from the time you get up until the race is over. Just wearing a monitor will probably remind you to relax some and it will also give you feedback concerning how uptight you are getting before a race. Remember, you have limited energy and it is best to use it in the race, not worrying about the race before it happens.

General Training Guidelines for Heart Rate Monitor Training to Develop Endurance, Power and Speed

**Maximal Range:** Training at 95 to 100 percent of max heart rate. Training in this range should be very limited. These are hard intervals that develop speed and anaerobic energy sources. They are done in short bursts to train for sprints, chasing the break-away or short hill jams.

**Threshold Range:** Training at 85 to 95 percent of max heart rate. This is pace or race training intensity. Most bicycle races are conducted in this range. Anaerobic threshold will occur within this range for most trained cyclists. This is the point at which the greatest aerobic improvement will occur.

**Base Range:** Training at 70 to 85 percent of max heart rate. This is where aerobic endurance is built and where most of your training mileage will be performed. Early season rides and long steady rides during season are conducted in this range. Training at these levels will develop and maintain your cardiovascular fitness and give you the necessary base to handle more intense workouts.

There are many things you can do with a heart rate monitor to help you in your understanding of training and racing. A great cyclist must also be a smart cyclist. A heart rate monitor is one of those tools that will help you get the most out of yourself. They can take much of the guesswork out of training intensity and serve as an excellent motivator on those days when you need that coach.

20 years ago Heart Rate Monitoring was the “tech” of the day. For the cyclist, a heart rate monitor could take the guess work out of training intensity and also serve as an excellent motivator for those days when the cyclist wanted to accurately evaluate performance and adjust training regimen. — Originally published in Performance Conditioning for Cycling Volume 1 #1
Training Age Considerations

Beginner – Resting Heart Rate: Strap your heart-rate monitor on at night, and in the morning you will have a good estimate to go by. You can begin to monitor for signs of overtraining or incomplete recovery.

Intermediate – Racing: During time trials, breakaways, or hill climbs a heart-rate monitor can be used to determine if you are going into anaerobic debt. For example, by not pushing too hard, you may save yourself from "blowing-up" on a climb, which will enable you to catch the group on the descent.

Advanced – Equipment: When evaluating new handlebars, crankarms, wheels or bikes it is important to use your heart rate monitor in conjunction with your stop watch. Ride a loop with different equipment and using checkpoints, check your speed for different pieces of equipment while riding at the same heart rate. This will give you an idea of which pieces of equipment are faster for the same energy output.

Beginning Masters: Maximal heart rate declines about one beat per year after the age of 20, but maximal heart rates can vary greatly for masters who are the same age. For example, a 40-year old cyclist’s maximal heart rate could range from 170 to 190 bpm. The best way to determine your maximal heart rate is having a stress test conducted under the direction of a physician, but if this is not a viable option, use the test outlined earlier in the article. 220 minus your age is a very inaccurate way for someone in serious training to determine their maximal heart rate.

Testing: Try I.T. Intensity Threshold to Test Lactate Threshold

Craig Calvin Jones

The "zone system" philosophy of training gained wide popularity. This system is an attempt for coaches to quantify and qualify an athlete's training, thereby making the "art of coaching" more scientific. Zone system training is commonly based around an athlete's lactate threshold (LT). The term "lactate threshold" is preferred to the common "anaerobic threshold"; by using lactate threshold it is clear that what is being measured is lactate.

Presented are common tests to measure lactic acid threshold and their strengths and weaknesses. — Originally published in Performance Conditioning for Cycling Volume 1 #2

What is the Lactate Threshold

Zone system training is commonly based around an athlete's lactate threshold (LT). The term "lactate threshold" is preferred to the common "anaerobic threshold"; by using lactate threshold it is clear that what is being measured is lactate.

Using lactate threshold training for a certain percentage of your total training volume will stimulate your body to adapt to going hard in a break-a-way, time trialing or climbing a steep hill in a mountain bike race. Most importantly, you will increase the percentage of your VO2 max that you can effectively use before the debilitating effects of lactic acid buildup and burning sets in. In other words, you will improve your ability to maintain a fast pace.

Lactic acid is present in normal working muscles, and is the by-product of anaerobic metabolism. It is processed by the body. As the workload is raised, the lactate is produced at an increasing rate. At some point, we are unable to match this increase in lactate with increases in its processing. Physiologists call this point the lactate threshold. They draw blood in order to measure the lactate level in the blood. This is the only truly accurate method of measuring LT.

<table>
<thead>
<tr>
<th>TESTS</th>
<th>DESCRIPTION</th>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiology Lab Test</td>
<td>Trained physiologists draw blood during a stress test at set intervals to accurately estimate the level of lactate.</td>
<td>Consistent results by trained personnel.</td>
<td>Expensive, and impractical to repeat when monitoring changes in Training Programs.</td>
</tr>
<tr>
<td>Test Conconi</td>
<td>A progressive stress test that claims HR flattens at the Lactate Threshold.</td>
<td>Claims to accurately predicts LT.</td>
<td>Other physiologists have found no correlated to LT.</td>
</tr>
<tr>
<td>Formula Systems</td>
<td>Uses age less a constant figure, or uses a maximum HR found by some test.</td>
<td>Easy to figure out.</td>
<td>Assumes a consistent level of training, and depends upon &quot;average&quot;, Max HR not always consistent.</td>
</tr>
</tbody>
</table>
**Effects of Lactic Acid**

The point at which lactic acid begins its climb is associated with a "burning sensation" in the legs. It also becomes more difficult to breathe, which makes speaking difficult for the rider. At this point, lactate has begun to accumulate in the muscles. Experienced riders know that during a time trial, it is best to maintain an intensity level close to this point. More effort than this, and the legs begin to burn and become sluggish.

**Beginner:** The last common method is the "talk-test" or "feel test". This system is the simplest and has the most credibility outside of the lab. If you have no access to a lab, the test protocol below can assist in setting parameters for zone system training. After all, for coaches, monitoring the workouts is the real purpose of LT.

The test described here is admittedly subjective, and relies on the ability of the rider to be honest with themselves and with you. It may result in heart rate close to the athlete's LT, but because we are not actually measuring lactate, we should not call this point the lactate threshold. We are trying to find a point at which a rider can no longer hold a sustained intense workload, and then measure this point in terms of HR. The point will be called the Intensity Threshold, (IT) for purposes of this article.

The protocol and checklist below are designed to bring a rider from a state of being warmed up, to a level of burning legs and being unable to speak easily. It is simply an over-engineered "talk test". We hold as many factors fixed as possible, then increase workload to find the HR where burning begins.

Coaches hope to see changes happen through training. First, the rider may raise their IT, allowing them to tolerate higher lactates. This we hope means they will go faster. For example, early in the year, our rider tests out with a 150 beat per minute (BPM) in the IT test. After three months of training, the IT is now 165 at a higher workload. They are now able to ride comfortably at the workload that caused burning legs a few months earlier.

The other change may be that the IT (and their actual LT) may not change, but they may be able perform a larger workload at this level. For example, the IT is 160 BPM, turning a gear of 53 x 14 at 90 rpm. Later in the season, the IT is still 160 BPM, but the workload is now a 53 x 12 at 90 rpm.

Racing of course will demand erratic jumps in workload and HR, but for purposes of assigning zones for training, the rider should bring the HR up slowly. This test is not a "gut blowout" test. The rider is simply brought up to a level of discomfort. They should be able to "road test" the estimated LT the next day.

Remember that when the rider is feeling an intense "burn", they are probably just past the LT. Note the HR at this point, but also look at your notes regarding the previous level. Assign an estimated LT a bit below the intense "burn" level. Also, you should give a range of 5 BPM for your estimated LT. Again, fine tuning should be done on the road.

The primary purpose of the IT checklist is to estimate LT. If you use macro and micro cycles in your training programs, it is necessary to re-assess LT at least once per macro, say once per month. Hopefully, the athlete will becoming more fit.

**INTENSITY THRESHOLD (IT) PROTOCOL AND CHECKLIST**

1. **Equipment needed:** Bike, wind trainer (or magnetic type trainer), stop watch, heart rate monitor, a large fan to cool the rider, and the IT Checklist. Write down rear cogs and chainrings on checklist. Use a gear chart to determine gear ratio or development. List the sprocket combinations (53 x 16, 42 x 16, etc.) on table below this. Begin on right with the highest ratio combination, then proceed to the left with the next lowest combination. This allows the coach to change resistance in a controlled manner to increase heart rate. A cadence monitor is useful but not required. Coach can also check approximate cadence with 6 seconds count and multiplying by ten.

2. **Set bike on trainer.** Check tire pressure, and set to 90 psi. Have rider sit on bike in normal position, and back roller off of tire completely. Slowly spin wheel and look for "high" point of tire. Slowly tighten roller knob until roller gently touches the tire. Tighten roller adjusting knob exactly one turn clockwise from this point.

3. **Place HR monitor and stop watch so both rider and assistant can see them.** Rider warms up wearing heart rate monitor. Ride small ring with lower gears (42 x 16, 42 x 17, etc.) at least 10 minutes. Rider maintains approximately 90 rpm (higher or lower if it is the rider's natural style). This agreed upon cadence should be maintained for entire test. Enter this cadence on the checklist.

4. **Assistant notes heart rate at end of warm-up session.** For a less fit rider, use this rate as the first level of the test. Rider is in fit condition may begin at higher than this warm-up level.

5. **Assistant begins stop watch.** Rider continues to maintain the heart rate noted in item #4 above for 5 minutes. Coach notes gear combination used on checklist.

6. **At 5:01 minutes, rider selects next highest gear combination.** Attempt to raise heart rate approximately 10 BPM above previous HR. Coach notes gear ratio used at each heart rate on checklist. If there is no change in HR, move on to next higher gear ratio. (NOTE: If rider seems to settle at an 8 or a 12 BPM increase, simply record this HR on checklist. The 10 BPM increase is a guideline, and deviations are permitted. The HR should be allowed to stabilize at the given workload.)

7. **At 10:01 minutes, rider shifts to next gear ratio higher in attempt to raise heart rate another 10 BPM.** This process continues.
Every 5 minutes, rider shifts to higher ratios to raise heart rate approximately 10 BPM above previous level.

8. Coach should be observing, and at times should talk with the rider. Attempt to hold a conversation and ask questions during last minute at each level. Coach should note:
   a. If rider can not concentrate on subject matter without cadence dropping off.
   b. If rider appears to labor in speech and in breathing.
   c. If rider's words "drop-off" at end of sentence.

### INTENSITY THRESHOLD CHECKLIST

<table>
<thead>
<tr>
<th>RIDER: ______________________</th>
<th>DATE OF TEST: ____________</th>
<th>ESTIMATED LT = ____________________________</th>
</tr>
</thead>
</table>

**GEAR RATIOS:** use gear chart and enter gear ratio below. (see back of USCF rule book)

<table>
<thead>
<tr>
<th>Rear Cog Position</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chainrings ↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List sprocket combinations. Begin with highest on right, then list next 12 in descending order to warm-up gear.

**LOWER RATIO COMBINATIONS...**  ...**HIGHEST RATIO COMBINATIONS**

<table>
<thead>
<tr>
<th>CADENCE FOR TEST: _____</th>
<th>WARM-UP TIME: _____</th>
<th>WARM-UP GEAR USED: ____ x ____</th>
</tr>
</thead>
</table>

HR AT END OF WARM-UP: ____ = beginning HR for 0-5’. Attempt to raise approximately 10 BPM for each target HR below. When first signs of stress appear, attempt to add 5 BPM at each following level.

<table>
<thead>
<tr>
<th>TEST TIME</th>
<th>HEART RATE</th>
<th>GEAR COMBINATION</th>
<th>Rider can speak easily?</th>
<th>Lactate burning?</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 5 minutes</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>5:01 to 10</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>10:01 to 15</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>15:01 to 20</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>20:01 to 25</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>25:01 to 30</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>30:01 to 35</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>35:01 to 40</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>40:01 to 45</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>45:01 to 50</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>50:01 to 55</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
<tr>
<td>55:01 to 60</td>
<td></td>
<td></td>
<td>YES NO</td>
<td>YES SOME NO</td>
</tr>
</tbody>
</table>

Estimated LT @ __________________ BPM
HR where rider could not maintain cadence ____________ BPM
d. If rider's sentence structure changes, becoming shorter.
e. If rider begins spitting, or if head begins dropping down or bobs up and down.
f. Rider should also be questioned to "burning" sensation in legs. Slight burning is normal as rider approaches LT. Note heart rate where slight burning occurs, and where also where significant burning begins.

10. If you feel the rider is close to LT, attempt to raise HR by only 5 BPM. Use a slightly higher cadence rather than shifting to next larger gear to achieve these smaller increments in heart rate.

11. Proceed as above, and note HR where rider is unable to maintain cadence.

12. Return to warm-up gear combination and spin easy to cool down.

13. When the rider is feeling an intense "burn", they are probably just past the LT. Note the HR at this point, but also look at your notes regarding the previous level. Assign an estimated LT a bit below the intense "burn" level. Also, you should give a range of 5 BPM for your estimated LT. Again, fine tuning should be done on the road.

14. Within a day or two day, re-test estimated LT on road. Warm-up 30-45 minutes, then work up to LT, increasing again by approximately 10 BPM. Attempt to hold 20 minutes. If rider is unable to hold for 15-20 minutes, then lower LT 5 BPM. If the interval seemed easy, it may be necessary to raise estimated LT.

The purpose of coaching is to assist the athlete in crossing the finish line first. Getting a higher VO2 Max., or a higher lactate threshold, or more power is merely a by-product of trying to win. It is easy for the coach to become lost in the physiological sciences, especially when there are so many neat toys and games to play. Heart rate monitors are one toy that is very useful, and the new training techniques are showing good results. Again, be careful that the training and the testing does not get in the way of racing. The sciences are here as a servant of the sport, not as a means to itself. There is no prize for highest lactate threshold.

Off-Season: Off-Season:
Change Gears in the Off-Season for Improved Mountain Bike Performance

Skip Hamilton

Our first mountain bike article. The pros even agree about the nature of their sport: beyond just the physical demands of coordination, endurance, and power (that elusive combo of strength and cadence), there’s the whole dimension of watching and concentrating on what terrain you’re about to ride through. So it’s no wonder that after a challenging ride, mountain bikers experience that incredible feeling of exhaustion (rewarding and fulfilling though!?). What you do in the off-season is as important as what you do in the on-season. January in Colorado: Ned Overend and Daryl Price skiing the cross-country tracks of Durango; Sarah Ballanyne off to do a peak climb on snowshoes in the Ten Mile Range near Breckenridge. — Originally published in Performance Conditioning for Cycling Volume 1 #4

The purpose of coaching is to assist the athlete in crossing the finish line first. Getting a higher VO2 Max., or a higher lactate threshold, or more power is merely a by-product of trying to win. It is easy for the coach to become lost in the physiological sciences, especially when there are so many neat toys and games to play. Heart rate monitors are one toy that is very useful, and the new training techniques are showing good results. Again, be careful that the training and the testing does not get in the way of racing. The sciences are here as a servant of the sport, not as a means to itself. There is no prize for highest lactate threshold.

Here's another concept the pros and coaches agree upon. What you do in the off-season is as important as what you do in the on-season. January in Colorado: Ned Overend and Daryl Price skiing the cross-country tracks of Durango; Sarah Ballanyne off to do a peak climb on snowshoes in the Ten Mile Range near Breckenridge, Mark Howe exploring the snowy back roads of Boulder County on his cyclocross bike, Tammy Jacques-Grewal and husband Rishi ski the way to Maroon Bells. There are few exceptions to this important realization that you've got to get away, both mentally and physically, from your mountain bike...
for an extended period of time. Since "the season" for most of the U.S. is March through October, either by way of competition or the rideability of the usual trails, the remaining four months have been dubbed the "off-season."

This is the time of year to get fresh again, to steer clear of your mountain bike, your regular rides, and most of all even thinking about usual training or what your goals might be for the next season. Goal setting in the off-season tends to create a preoccupation with riding and cycle-training, the results of which will leave you mentally fried even before you get on your bike. The off-season is a time of year to approach all of your exercise with adventure in mind: lots of cross-training, new territory, maybe a new mode of aerobically getting around. And along with all important fresh outlook that you now have on your "training" (get the bike out of your mind and out from under your body) here are the essentials of gaining fitness that successfully launch your season when you do get back on your bike.

1. **Aerobic base building:** Continue with a major emphasis on low intensity (< 75% of max = USCF zones 1 & 2 ) efforts in a variety of kinds of exercise that appeal to you. If you live in or near snow, try cross-country skiing (both the traditional classic and the newer skate skiing), or running or walking on these small snowshoes that are becoming popular, ice skating or speed skating. In non-snow climates, take on running trails (no more than two days in a row, unless you're a regular runner), in-line skating with proper technique (and a helmet!), laps in a pool, whatever! If it represents aerobic exercise for a chance of an average of one hour a day, and you like it, do it! Mix up the kinds of activities so that the novelty factor stays high. The more you can include your whole body in these workouts, the better. For example, running on snowshoes is more complete if you use alpine ski poles as part of your stride; same with in-line skates. Upper body aerobic conditioning is just as important as lower. If you're able, do one longer session per week (2-4 hours), keep it conversational pace, make it a social outing with friends. The other tangent to take is a mid-week set of "subtle surges" (half click up, half click down in pace) from the usual aerobic intensity. In Sweden this is called "fartlek" and means informal speedplay, sort of a low key flow follow the leader. It’s fun and just mixes it up a bit, especially if you're enjoying a "newer" sport in your off-season. If you really have to ride a bike now and then, cycle in a way that's totally different for you: adventure rides in fresh powder snow or on snowmobile tracks (ugh!), explore all the back roads you can find on a cyclocross bike, or even some easy road rides that let you be with friends and socialize, or just drift off in thought. Indoor trainers only if you have to, or are experiencing acute saddle-time withdrawal.

2. **If it's uphill, it really counts!** Whatever uphill technique it is, if you get there under your own power, it's great for your fitness and conditioning. Again, the upper body involvement is icing on the cake. Others: Stairmaster, uphill treadmilling, rowing machines!

3. **Strength:** All of the exercising mentioned, when properly done, incorporate strength building. These are easy ways to gain base building for endurance and strength. If you like the gym, two sessions a week plus your aerobic work is plenty; keep the weights light, medium number of reps, two sets, and do a real variety. Circuit training in the weight room or through a set of machines keeps the fun and novelty. As always, do your abdominal work (crunches) and related lower back exercises (extensions).

4. **Flexibility:** if you're a regular stretcher, keep it going. If you're new to stretching, this is a good time to start an important habit. It feels good, is good for you (and your riding) and should become a daily ritual for all serious athletes. Stretching when you're warmed up, or just after a workout is best.

The winter months are a great time for trying new and different modes of exercise. It's a time for fun and adventure, for new learning, and most importantly it's a chance for a fresh perspective on working out that takes your mind and body off of your bike. You'll be raring to go come spring, the base building and conditioning will be there, and mentally you'll be energized and eager to take on those extreme demands of mountain biking, and with a little planning (next issues!), you'll last the whole season of riding and enjoyment.

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**OFF-BIKE: STRENGTH TRAINING AND CYCLING - TAKE ANOTHER LOOK**

Vern Gambetta

Strength training takes on a more global application beyond lifting weights. This opens the door to many ways to accomplish strength gains. Strength training is gaining more acceptance that in some form, is necessary to improve cycling performance. — Originally published in Performance Conditioning for Cycling Volume 1 #1

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**S**

Strength training is an umbrella term that encompasses more than just overcoming resistance of lifting weights. According to Bompa (1994) "Gains in strength is the result of increasing tension in the muscles by activating a quick and powerful contraction." There are many ways to accomplish strength gains if one accepts this premise. In fact the possibilities are unlimited especially for cycling. It is becoming more accepted that some form of
strength training is necessary to improve cycling performance. The whole issue of strength training for cycling is a wide open vista waiting to be explored. It is the human engine that is the propelling mechanism that powers the bike therefore any increase in power production should have a positive benefit on cycling performance.

Cycling is an endurance dominated activity, that also requires the ability to sprint at the end of a race, respond quickly to a breakaway or hold the most aerodynamically efficient position for long periods of time. All of this is highly dependent on strength. Conventional wisdom has held that strength and endurance are fundamentally incompatible. Current thinking does not reflect this. The two qualities can be developed in parallel in a properly designed program that incorporates the principles of periodization. Traditionally strength has been aby circuit training or weight training in the off season with a maintenance program in season. There was always the fear of added bulk, especially in the upper body and tightness in the legs especially if the program was continued in the competitive season. In short the same myths that prevail about strength training in many other sports also prevail in cycling. As in the other sports, these myths are unfounded in practice. The myths have no foundation in truth if the goal is to develop functional strength - strength that can be used to enhance performance and prevent injury.

In order to understand how to develop functional strength we must understand several key concepts:

**Core Strength Before Extremity Strength**

The core of the body consists of the hips, abdomen and low back. These areas are essential for postural alignment and stability to maintain an efficient aerodynamic position on the bike. A weak core will result in wasted motion and inefficient force transfer to the pedals, especially with the onset of fatigue.

**Body Weight Work Before External Resistance Work**

The cyclist must learn to handle his or her own body weight before attempting external resistance exercises. This principle adds versatility to a cyclists program in that the program is not bound to machines, apparatus or equipment. The body is the ultimate free weight.

**Strength Before Strength Endurance**

Strength is the quality that you are trying to endure therefore strength must be developed first in order to be able to endure it. This is closely tied to the previous principle and the following principle in that the ability to effectively handle one's own body as resistance is fundamental.

**Synergistic and Stabilizing Muscle Strength Must Be Developed Before Gross Strength in the Prime Movers (working muscles)**

The prime movers work more efficiently and effectively when the stabilizers are strong. A weak stabilizer will inhibit the contraction ability of the prime mover.

These concepts have direct implications for the selection of the mode of strength training as well as the ability to fit strength training into the overall training program. Ultimately any training program must be personal, practical and proactive. To be personal it must fit the needs of the individual cyclist. In order to be practical it must be able to be accomplished in the time allocated with the space and equipment available. Finally to be proactive the training must anticipate potential obstacles and roadblocks.

**Favorite Cycling Strength Exercises from the Experts - The Lunge**

Develops Integral part of the cyclists leg strength program. It is an essential multi-joint leg exercise that work the gluteus, hamstrings, and quadriceps groups with the hip abductors and adductors working as stabilizers. It should be used in conjunction with several other multi-joint leg exercises to develop leg power and to prevent injury.

**How To**

Begin without and resistance to learn the correct rhythm and execution of the movement. Start standing with the trunk erect and the feet parallel shoulder width apart. Step out onto one leg allowing the weight to transfer to the stepping leg. As soon as there is a ninety degree bend in the front leg push back up to the starting position and execute the same movement with the other leg. Keep an erect trunk throughout the movement in order to insure maximum flexion at the hip in order to stress the gluteus maximus. The rhythm without any external resistance is one rep per second as long as balance can be maintained. The amplitude of the movement is to stride as long as you are tall in order to insure extension of the back leg. Resistance can be added by holding a dumbbell in each hand, a sandbag draped
over the shoulders, wearing a weight vest or a barbell on the shoulders. Variations include execution of the lunge while walking forward, lunging onto a four inch high box to minimize stress on the knee, and lunging down off a four inch high box to increase eccentric loading.

Common Errors

Too short a step out. Bending at the waist as the forward step is taken. Inability to balance by starting with too narrow a base.

Sets, Reps, Loads

Begin with three to four sets of ten to twelve reps on each leg with only body weight as resistance. Progress to four to five sets of five reps with external resistance. The resistance should not be so great as to compromise the speed or amplitude of movement.

Tactics: The Science of Drafting - Easy Riding in the Slipstream

Jeffrey P. Broker, Ph.D.

It is common knowledge that drafting, or riding in the “slipstream” behind other riders, reduces aerodynamic drag forces which critically affect the effort required to ride at a given pace. Racers use drafting to increase speed without increased effort. Recreational riders can use drafting to ride longer without fatigue. To be a complete cyclist, full respect and appreciation of the science of drafting should be developed.

In this article, the science of drafting will be explored. Questions we will address in our exploration of drafting science include:

- What is the energy savings while riding behind one, two, and three riders?
- How important is wheel gap to draft effectiveness?
- Do I benefit when someone drafts me?
- What are the "rules" of pacelines?
- How about packs? Are packs as good as pacelines?

What is Drafting?

Drafting in cycling simply means riding in the wake of riders up ahead. While drafting, riders take advantage of an artificial tail wind generated by the movement of other riders through the air in front of them. The presence of this tail wind is easily observed when automobiles pass close to bushes or over pieces of paper, cardboard, etc.

How is the effect of drafting measured? In general, four methods have been used to study drafting. The most expensive method requires a wind tunnel. Chester Kyle, Ph.D. used wind tunnels in the early 1980s to test the effect of drafting on cycling aerodynamics, and we use wind tunnels today (with Dr. Kyle) to evaluate U.S. National Team riders. Riders are positioned in the wind tunnel in various numbers and arrangements and the drag forces are measured directly. A lower cost method to evaluate the effects of drafting involves coast down tests. In these tests, rider and bicycle deceleration rates are measured while coasting in zero wind conditions from initial speeds of up to 35 mph. Since deceleration is directly proportional to the resistive forces acting on the bicycle and rider (aerodynamic and rolling), and since rolling resistance doesn't vary in draft situations, the separate effect of drafting on aerodynamic drag can be calculated.

A third method to study drafting, pioneered by James Hagberg, Ph.D. and his associates, involves the direct measurement of oxygen consumption while riding on the road. Hagberg fabricated a boom-mounted oxygen breathing apparatus that permitted the evaluation of drafting conditions on energy expenditure. Since this method measures physiological response to drafting arrangements, it has direct application to real world situations. The fourth method requires on-board instrumentation to measure bicycle power output. Power output is typically measured at the cranks or at the rear hub. These instrumentation devices have become available in recent years, and we use these devices with U.S. National team athletes (road and track) at the Olympic Training Center in Colorado Springs. Because these on-board instrumentation systems simultaneously measure both speed and
bicycle power, uniform speed over lengthy intervals (6 to 7 minutes for the oxygen measurement tests) is not required.

Fortunately for all of us, the results obtained using the different methods are in general agreement. Differences between methods can generally be attributed to unique features of the experimental setup (riders and bicycles used, conditions studied, etc.).

The Effects of Drafting

In general, drafting at speeds above 20 mph will result in an energy savings of between 20 and 40 percent. The factors that cause the effect to vary from 20 to 40 percent, admittedly a huge range, are as follows:

**Speed Effect**

The faster you ride, the greater the energy savings resulting from a given type of draft (Figure 1). Dr. Kyle determined that when one rider drafts another, the following rider enjoys a 38 percent decrease in aerodynamic drag relative to the leader. Dr. Kyle indicated the 38 percent decrease was constant across speeds (from 15 to 33 mph). However, because a lead riders' energy consumption increases dramatically with speed, the absolute amount of energy saved by drafting increases with speed (e.g., 38 percent of 400 Watts is more than 38 percent of 200 Watts). When Kyle adjusted his estimate to include the effect of rolling resistance on bicycle power output, a total energy savings of 29 percent at 15 mph, and 35 percent at 35 mph resulted.

In Dr. Hagberg's oxygen consumption tests, the total energy savings resulting from drafting a single rider was roughly 18 percent at 20 mph, and 26 percent at 25 mph. The reason for the discrepancy between Dr. Kyle's results and those of Dr. Hagberg's is not completely apparent. Data collected on U.S. National team riders, however, indicate that significantly more than 35 percent savings can be achieved at 25 mph if draft alignment and wheel spacing is carefully controlled. Consequently, the effects of test conditions on the results reported by Kyle and Hagberg may be important.

**Pace Line Position Effect**

The lead rider in a pace line does not benefit from the drafting process. Although this may seem obvious, some aerodynamicists have suggested that a region of increased pressure forms ahead of the drafting rider, and this increased pressure region may assist the lead rider. To date, however, no measurable effect of drafting on a lead rider has been identified.

By contrast, following riders benefit significantly from drafting. If two riders form a pace line at 25 mph, the front rider consumes the same energy as if riding solo, while the second rider consumes about 27 to 33 percent less energy. Does the draft effect change within the pace line if more riders join in? Surprisingly, there appears to be little difference in energy consumption between the 2nd, 3rd, or 4th positions in a pace line (Figure 2).

The number of riders in a pace line does have a significant effect on the speed at which the group can ride. This group effect occurs because the greater the number of riders participating in the rotating pace line, the more time each rider spends in the lower energy draft positions. Using Dr. Kyle's data, for example, four riders capable of riding 25 mph without the benefit of drafting should be able to ride approximately 27.25 mph at the same total energy expenditure as a group.

**Spacing (wheel gap) Effect**

As expected, the more closely one rider follows another, the greater the effect of drafting. The 38 percent reduction in aerodynamic drag reported by Dr. Kyle was with a wheel gap of approximately 12 inches. When the gap was increased to 78 inches (a
little more than one bike length), the aerodynamic drag savings was reduced to only 27 percent. At world class levels, team pursuers and team time trialers attempt to maintain their wheel gaps within 6 inches to maximize the advantage of close-gap drafting. Furthermore, the use of 26 and 24 inch wheels in team events is largely motivated by the spacing effect, i.e., smaller wheels place riders in a paceline closer together, which enhances the draft effectiveness.

If some overlap between the drafting riders' front wheel and the lead rider's rear wheel exists, alignment is not ideal (the drafting rider is to one side of the lead rider) and a decrease in draft effectiveness occurs. Dr. Kyle commented on this situation because it arose several times in his experiments. Kyle indicated only a 0 to 30 percent reduction in aerodynamic drag in the overlap position (depending on the magnitude of the overlap and the side-to-side spacing), compared to a 38 percent drag reduction for the aligned drafting condition with a 12 inch wheel spacing. Given the negative effect on draft advantage and the inherent danger of riding in this position, it is wise to avoid the overlap situation in pacelines.

Body Size and Positioning Effect

The effect of drafting a large, upright rider is obviously greater than drafting a small rider in a tucked, aerodynamic position. But how large is the effect? Dr. Kyle reported that an upright rider in an upright pace line experienced a greater percentage reduction in wind resistance than a rider in a racing position in a racing position pace line. As Kyle pointed out, however, the upright rider consumes more energy than the racing position rider, because of the effect of position on baseline aerodynamic drag.

Kyle did not study the effect of a streamlined, racing position rider drafting an upright rider.

With U.S. National team pursuers, we also see a marked influence of rider size, shape, and position on draft effect. In summary, large riders, and normal size riders with wide shoulders, provide an advantageous 'slipstream' for following riders.

Arrangement Effect

We've indicated that with the exception of the lead, position within a paceline has no effect on draft effect. How about pack riding? Dr. Hagberg reported a 39 percent reduction in energy expenditure when riding at the back of an 8-rider pack. This energy savings is compared to his 27 percent reduction in paceline drafting. Kyle studied a single pack of three riders in an open V-formation (Kyle actually ran his tests in a 200 meter long hallway!) and found a reduced draft effectiveness for the single rider in the rear. Kyle's arrangement, however, placed no rider immediately forward of the drafting rider.

Applying Principles of Draft

Having developed some understanding of drafting, we can now apply what we know to racing, training, and just plain riding.

• When drafting, try to stay directly behind other riders if possible. In packs, align yourself with at least one bicycle ahead of you.
• Six- to twelve-inch wheel gaps are safe and effective for experienced riders. As wheel spacing increases, so does aerodynamic drag in the drafting position.
• Over a given race course or training ride, you can ride faster in a paceline for the same energy expenditure. Don't be alarmed when you discover you and your riding group are speeding along some 2 to 3 mph faster than you normally ride alone.
• At the same speed, you spend considerably less energy while drafting. Maybe you feel under the weather one day, or need a recovery day after a hard week. Sitting on somebody else's wheel at your usual pace will save you energy, and save your legs.
• Riders behind you are resting. Being in front is a great place to be if you're trying to build endurance, but at a third more power than everyone else, you probably won't last long in this position.
• In races, select larger riders to draft if possible, or riders who sit more upright on their bicycles. Saving your resources in this manner may leave you with just that extra burst of energy needed to place in the top group.
• When your competitors are drafting you, stay aerodynamic. Keeping streamlined reduces the effective draft your opponents receive from you, and therefore they must tap deeper into their energy stores.
• We've established that the effect of drafting on energy expenditure increases with bicycle speed. Headwinds also increase the effectiveness of a good draft.
• In cross winds, draft behind and slightly to the downwind side of the lead rider. The stronger the cross wind, the more to the side of the lead rider you should be. Be careful to monitor dangerous wheel overlap in these circumstances.
• Weaker riders can survive in pacelines due to the reduced energy expenditure in the draft positions. Weaker riders, however, can slow a paceline. To drop a weaker rider, accelerate the paceline while the weaker rider is in the rear position and hold the increased pace until they drop back.

For the Beginner: Learning to Ride in Pacelines

• Play it safe at first. Ride an entire bike length behind other riders when learning to draft. Here, you'll have time to react to sudden changes of direction or pace. Don't reduce your wheel spacing until you can hold a steady, smooth pace at a constant wheel spacing.
• Follow experienced riders at first. Experienced riders ride in straight lines with minimal changes of pace. If you find yourself behind a jerky, hesitant rider, increase your wheel spacing.
• Don't become mesmerized by the wheel in front of you. Pay attention to upcoming events such as turns, bumps, etc.
• When it's your turn to lead, maintain the pace in effect before you took the lead position. If you encounter a hill while leading,
The aerobic system utilizes the endless supply of oxygen and fat as its primary source for energy production. This system is well as aerobic systems.

In contrast to the inefficiency of the anaerobic system, the aerobic system is much more efficient at processing stored energy, such as glyco- gen and fat, into energy that can be used for muscle contractions. In theory, the more efficient a rider becomes at producing energy, the faster he or she will go. (I say in theory because there are so many other aspects in our sport. Technical skills, bike handling and equipment, just to name a few.) Basically, there are two systems in both men and women that can produce energy for muscle contractions, the anaerobic and the aerobic energy systems. The anaerobic system is able to produce energy very quickly without using oxygen while the aerobic system is much slower and requires oxygen.

To produce energy quickly, short intense efforts lasting 10 to 20 seconds rely primarily on blood glucose and stored glyco- gen in the muscle. A road racer who must produce lots of power very quickly in order to win sprints and primes, or a match sprint- er on the track rely heavily on the anaerobic energy systems. As we all know, the anaerobic energy systems also produce large amounts of lactic acid. The lactic acid is the byproduct that causes the burning sensation in your legs during hard efforts. When the muscle begins to produce lactic acid faster than it can be cleared, lactic acid begins to accumulate in the muscle and fatigue sets in.

The critical factor in a cyclist’s performance is how well they have trained their body to turn stored energy, such as glyco- gen and fat, into energy that can be used for muscle contractions. In theory, the more efficient a rider becomes at producing energy, the faster he or she will go. (I say in theory because there are so many other aspects in our sport. Technical skills, bike handling and equipment, just to name a few.) Basically, there are two systems in both men and women that can produce energy for muscle contractions, the anaerobic and the aerobic energy systems. The anaerobic system is able to produce energy very quickly without using oxygen while the aerobic system is much slower and requires oxygen.

Maximal oxygen consumption (VO2 max) is a term loosely used in the sport world to describe aerobic capacity. Technically, maximal oxygen consumption is defined as the highest oxygen uptake an individual can attain during exercise. This is typically measured in an exercise physiology lab with a cyclist hooked to an apparatus that measures the amount of air inspired and expired, along with the amount of oxygen that goes into the athlete and the amount of oxygen that comes back out. Using a series of calcula- tions, the amount of oxygen used by the athlete’s tissue can be determined.

Are the physiological demands placed on the female cyclist during training and competition any different than the physio- logical demands placed on the male cyclist?

While both men and women respond to acute exercise and adapt to training in much the same way, there are several areas which are unique to the female cyclist.

The factors that contribute to an athlete’s VO2 max include genetics, training, physical condition, body weight and gender. An athlete’s baseline VO2 max is a gift from their parents, but it can be increased with proper training. Genetics seems to be the predominate factor in how much someone can train their VO2 max, and research has shown that both men and women can experience the same relative increase with the proper training.
For both men and women, the measurement of VO$_2$ max is dependent on two things;

1. the ability of the muscles to extract and use oxygen to produce energy and
2. the capacity of the heart and blood vessels to deliver blood to the working muscles.

The process by which men and women use oxygen to produce energy is essentially the same. However, research has shown that elite women athletes have 65 percent to 75 percent of the absolute aerobic capacity of men. Absolute is the total amount of oxygen consumed, with no corrections for height, weight or body size. One of the most obvious differences between men and women is that women are smaller (on average 13 cm shorter and 15 to 18 kg lighter), so a direct comparison of absolute oxygen consumption is not really fair. When using relative numbers that have been corrected for body weight (ml of O2/kg body wt per min) women still possess only 75 percent to 85 percent of the relative aerobic capacity of males.

What causes this difference? One theory is the lower hemoglobin concentration found in women’s blood. Hemoglobin is responsible for carrying oxygen; therefore the oxygen-binding capacity of women’s blood is lower. Another factor all women are painfully aware of it that women carry more body fat than men. Since fatty tissue is metabolically inert (it just sits there), the metabolic cost of riding at a given speed will be higher for someone with more fat. Even so, if we take body fat out of the picture and comparisons are made based on lean body mass, the difference in VO$_2$ max falls to approximately 10 percent.

As mentioned earlier, both men and women can utilize both carbohydrate and fat as fuel for energy. The difference in fuel utilization during exercise between male and female athletes has become a hot research topic. During moderate-intensity exercise, women demonstrate greater fat utilization and less carbohydrate utilization than their male counterparts. The difference may be due to the female hormones estrogen and progesterone. Both hormones have been shown to cause a greater dependence on fat for fuel, lower blood lactate levels during moderate exercise and higher levels of free fatty acids in the blood. These female hormones enhance glycogen storage and uptake. Combined with a greater dependence on fat for fuel during exercise, female athletes have been shown to utilize less glycogen during low to moderate intensity exercise. All of these factors together may indicate a greater ability for endurance exercise in the female cyclist!

One of the most obvious differences between men and women is their body composition, the relationship between lean body weight and fat weight. Total body weight is divided into lean body mass (muscle, bone and organs) and fat weight (essential and storage). Essential fat includes the fat that is used to line nervous tissue, protect organs and, in women, perform necessary reproductive functions. Essential fat for female athletes is around 9 percent, while men require only 3 percent. Storage fat refers to the excess fat that accumulates in adipose tissue, usually right beneath the skin. The purpose of storage fat is for insulation and fuel for the production of energy. The amount of storage fat is similar between men and women, but because of a woman has smaller body size and less lean body mass, women typically have a higher relative amount of storage fat than men. Elite male endurance cyclists are typically in the range of 4 to 10 percent, while elite female cyclists average 10 to 18 percent.

Women who participate in endurance sports where low body fat is an advantage, such as cycling, are at risk for a triad of interrelated disorders. The “female athlete triad” is a phrase that was coined to describe a set of medical conditions that can occur in female athletes (see table below). As a female cyclist or the coach of one, it is critical to recognize the symptoms of this disorder and be able to refer those who may be at risk to qualified health care professionals. However, prevention is the best solution. It is important to realize that promoting a positive self-image along with realistic performance goals and stressing a sensible body composition go a long way.

Position Stand on the Female Athlete Triad

In May 1997, the American College of Sports Medicine issued a Position Stand on the Female Athlete Triad. In summary, it states that:

1. The Female Athlete Triad is a syndrome of three disorders—disordered eating, amenorrhea, and osteoporosis—that results in serious medical and psychological problems.
2. Pressures placed on girls and women to achieve or maintain unrealistically low body weights underlie the development of the Triad.
3. Symptoms of the Triad are often denied or not recognized.
4. Women with one component of the Triad should be screened for other disorders.
5. All sports medicine professionals, including coaches, should learn how to prevent and recognize the Triad. They should follow healthy training practices and know how to refer a women with the Triad.
6. Physically active girls and women should be educated about proper nutrition and the risks of the Triad.

Recovery: Tapering for the Competitive Cyclist

Joseph A. Houmard, Ph.D

Today, recovery is the next big thing. For the competitive cyclists it’s all about proper taping. The key factor influencing results is training, particularly in the days leading up to an important competition. — Originally published in Performance Conditioning for Cycling Volume 2 #7

C}ompetitive cyclists and coaches constantly try to attain peak performance for the most important competition of the season. Various psychological and physiological techniques are used for optimizing performance. However, perhaps the major factor influencing performance is training, particularly in the days leading up to an important competition. Many coaches and riders drastically reduce training volume for 7 to 21 days prior to a championship
race; this reduction in training volume is often incremental (Figure 1) and is termed a "taper."

The million dollar question surrounding taper is, "will a taper work for me, and if so, what kind of training program should I follow?" For cyclists, the answer is not yet clear; however, scientific findings can provide some useful hints. One study performed by researchers at the University of Wyoming examined the effect of a two-week taper on competitive collegiate cyclists. During normal training the cyclists were exercising 1 - 2 hours/day (about 9 hours/week); during taper training was reduced by about 70% to approximately 2 hours/week. This means that the cyclists were only exercising about 20 - 30 minutes/day during the taper; also, no training was performed on one day of the taper, thus reducing training frequency (days/week of training) by about 12%. The workouts during taper were similar to normal training in terms of the relative percent of "intense" work or intervals. With this taper, peak leg power and cycling performance improved after only one week; however, after two weeks of taper, performance and peak power were similar to levels seen during normal training.

Another study (reference 5) examined the impact of a 4- or 8-day taper on skeletal muscle. The cyclists were normally training about 60 minutes/day; during the 4-day taper they trained 60, 40, 20 and 0 minutes on days 1-4, respectively. For the 8-day taper, cyclists trained for 60, 60, 40, 0, 40, 20, 20, and 0 minutes on days 1-8 respectively. Muscle power output and muscle glycogen content increased after both the 4- and 8-day tapers. Several enzymes which are involved in the aerobic production of ATP also improved with both tapers. All of these adaptations suggest that performance would also have improved, although a time trial/race was not performed.

Studies looking at swimmers and runners have also reported an improvement in muscular power following a taper (references 1,2,3). The results of all of these studies indicate that a relatively short training period during which training volume is drastically reduced improves variables associated with cycling performance. It is evident that leg power in cyclists is enhanced with taper by about 10%.

A natural question is, why is an improvement in power important in an endurance event that relies primarily on aerobic capacity? The answer lies in the nature of many competitions. For individuals who are relatively evenly matched in aerobic capacity, many times the difference between winning and losing depends on sprinting ability. Sprinting ability, in turn, is heavily dependent on how much power you can exert. This may be particularly relevant in cycling where it is common to ride in the pack and draft until relatively late in the race, and then sprint to the finish. The improvement in power that comes with a taper is thus very important to a competitive cyclist.

However, does this mean that a pre-competition should exactly mirror those used in the two studies described here? Not necessarily. This is where the "art" of coaching comes into play. A coach with many years of experience should be able to customize a taper for an athlete based upon his/her training background and competitive experiences. However, many competitive cyclists are self-coached; the design of a taper thus has to be essentially guessed at.

For hints about tapering we need to look at studies performed in other endurance sports such as distance running and swimming. To roughly summarize the literature, it appears that taper should consist of a gradual reduction in training volume (60 to 90% reduction in total weekly volume) over a 7- to 14-day period. Training during taper should primarily consist of work performed at race pace or slightly faster. Training frequency should be reduced by no more than 20%. In endurance athletes, tapers within these guidelines have been shown to improve muscular power and exercise economy, increase muscle glycogen content, and increase muscular aerobic capacity. More importantly, performance in actual time trials or races has been shown to increase by 3%.

This figure is important, as the athlete or coach must have a reasonable indication of how much performance will increase with taper. By allowing for a 3% improvement, appropriate pacing and race strategies can be developed. While 3% may not seem like much, it can make the difference between winning or losing in a close competition.
The numbers in Figure 1 represent a typical 7-day taper for an individual training 150 - 200 miles/week (7 - 11 hours/week). Follow these numbers as a suggestion only, and don’t be afraid to experiment; the important factor is to stay within the guidelines presented above.

It is not clear how many times during a season one can successfully taper, nor how closely such tapers can be spaced before the beneficial effect is lost. Such decisions are left to the discretion of the athlete/coach as currently there are no scientific studies addressing these topics.

Although the guidelines are fairly broad, the message is clear: TAPER IF YOU WANT TO PERFORM YOUR BEST. Such “rest” will result in optimal performance. During taper you may feel “heavy”; some think that this is due to the increased glycogen storage or due to the “rest” being allowed to your body after intense training. Regardless, have a positive attitude and count on improving at that big race.

12 YEARS AGO: EVOLUTION OF TRAINING AND CONDITIONING PRACTICES IN CYCLING

Ed Burke, Ph.D.

My first experience in competitive cycling started with the 1976 Olympics. Most cyclists around that time didn't have a coach to work with. Instead, most were self-taught and coached. Training mostly consisted of just riding a bike. As a result, training was hit or miss for the most part. Neither the volume nor quality of training was near as much as it is today. Most importantly, training was not organized. It was mainly a matter of looking at what the best cyclists of the day were doing. Methods of training lacked the structure that we know today.

Evolution of Training and Conditioning Methods

Starting in 1977, the United States Cycling Federation (as it was known at the time) started to change the way cyclists approached their training by the hiring of their first national coach, Eddy Borysewicz. Eddy came out of the Eastern Bloc where he was former head of the Polish National Team. The Poles were one of the more successful teams in this region. Eddy was really the first one to bring over the concepts of organized training—quality of training with structured interval and tempo type training. This was the introduction of what we call periodization of training.

His concept took some time to catch on. Eddy started working with the national team as the 1980 Olympic coach and he worked through the middle of that decade. During this time, he was one of the first coaches in this country to start working with cycling athletes with resistance training on a large scale. Like with many things, it takes an outsider to come in and open peoples' eyes to new techniques. The type of training we did at the Olympic training center was a more volume type of training that worked the whole body. Also, during this time, he introduced on a minor scale the concepts of what is now known as plyometrics.

In the early 80s we started by doing some bounding, jumping and tumbling, mainly with track athletes. We didn't really know how to define it, but we knew it helped explosive power. This type of training was very short in duration—from November to January. The introduction of periodization, plyometrics and resistance training created team unity and enhanced the education of the coaches with whom he worked.

Also during the 80s, the biggest change that occurred was with the volume of training. Cyclists were entering longer races. Professional cycling increased in popularity. This lead to teams entering the Tour De France, starting with the 7-11 team. This aided the older and more experienced Cat 1 and 2 riders to realize that they had to increase their volume. In some cases, volume had to double for them to effectively compete. Using periodization principles allows for all this to start happening.

In the late 80s while I was at the Olympic Training Center, I started working with Harvey Newton. Harvey was coach of the USA Weightlifting team and an avid cyclist. We looked at ways to help resistance training evolve into a more scientific approach. This lead to development of periodization of resistance training that coincided with periodization of on-bike training.

Aerobic endurance periodization became linked with strength and power periodization. At first this information started to be picked up by track cyclists who were more of the strength/power athletes and who would directly benefit from these training concepts. In the early 90s, Chris Carmichael came along and started to adopt these concepts for some of his younger road riders. At this time, riders in Europe also started to adopt resistance training as an important part of their overall training; again, from a total body preparation perspective. They weren't necessarily concentrating on the legs but more on the core area of the back, abdominal muscles and shoulders, along with the arms in order to condition the body and prevent injury.

Today, more and more professional cyclists are adopting resistance training as part of their overall training regimens.
Even Lance Armstrong strength trains in the off-season. This is a major development for the sport.

Off-Bike Considerations

Most sports support resistance training during the season. Football players lift two to three times a week all the way up to the Super Bowl, and this makes sense. But we have to realize cycling is a different animal. Most cyclists drop resistance training during the season. This is a result of the many hours on the bike that is demanded of the athletes during the season. Resistance training just doesn't leave a lot of room to allow for adequate recovery.

What I've seen in the last few years, especially with the introduction of mountain biking, is the advancement of core training for cyclists. This is the new area of emphasis and development. It is an important development for cyclists, as their weakest link has always been the core area. Now, anything that can be done with supplemental training to benefit the body from the abdominal muscles and lower back up to the shoulders if welcome. Cyclists can make use of the many tools that are available including Swiss balls, balance boards, medicine balls, Pilate's, etc.

This type of training is more accessible to cycling athletes, and is most critical to mountain bike athletes. Their need for upper body and core stability and strength is greater due to being in and out of the saddle more, performing technical climbs and working around rocky trails. But endurance road cyclists will soon realize that if they can stabilize the core, it will allow for more force production to the pedals.

It will also help reduce fatigue and hopefully avoid long-term back problems. Another advantage is that core training can be done year round because cyclists don't have to go into the weight room to do it. It can be performed at home, which provides time efficiency during the busy season.

On-Bike Considerations

Starting in the 90s we saw a different approach that cyclists would take to racing. In the old days, a cyclist would race every weekend, with the mindset to race as often as possible. I think Lance Armstrong introduced a concept of peaking for certain events and using other races as training events. This goes against the thought for cyclists that, "I've got to win every race."

This thinking is along the line of the concepts of periodization, which states that during the year cyclists have several peaks. Today's athletes are racing to win less and selectively peak more. By doing this, they are also paying more attention to recovery, an area I'll address in detail later.

In the off-season, cyclists are doing more cross-recovery training in the form of active rest. Because the racing season is so long, starting in March and lasting through October, cyclists are realizing they need time off the bike.

The final renaissance of sorts during the last three years is the dramatic increase in the use of coaches by cyclists. Coaches can enhance the performance of cyclists in many ways. For example, in person or another set of eyes providing hands-on coaching twice a week. Alternatively, via e-mail, on the phone or with the aid of software packages.

Evolution of Cycling Lab Tests

During the 70s there wasn't a lot of physiological testing going on. In this country probably the first of such tests done to any extent with cyclists were performed in 1977 at the training center in Colorado Springs. Primarily, all we were testing was VO2 max. In addition, we also did the first lactate threshold tests. The only other place this was being done was over in the Eastern Bloc. We were testing, but we really didn't know what the results might mean for cyclists—we had numbers. If a kid came in with a big VO2 max and little else, we knew that at least s/he had a good engine. Hopefully, over time techniques, tactics and strategy could be taught.

In the 80s, max VO2 and lactate tests continued to be performed. At this time heart rate monitors started to arrive on the scene. This allowed us to gather heart rate information and combine it with laboratory information.

The next big step was advent of biomechanical testing. In the early 80s, I started working with Peter Cavanaugh and a group out of Penn State along with Bob Gregor of UCLA. We were examining pedaling techniques. All we were collecting was descriptive data. From that information, we were able to come back to cyclists and inform many of them that most of their effort was in the down stroke with hardly any force in the pull up. As simple as this may seem, it was a huge finding.

This was also the time that people started looking at the aero position, trying to see how it affected physiological parameters and pedaling mechanics. Our focus was to see if the aero position allowed for gain or loss of power. Was it restricting breathing and delivery of oxygen to the working muscles?

Though the 80s lactate threshold testing became more sophisticated, with the assistance of heart rate monitors we started to take what we were doing into the lab and apply it to on-the-bike conditions. This was important because we came to realize that physiological testing wasn't an end-all, be-all. Testing became a spoke in the wheel of a bigger picture in the sense that it gave us information; however, the true test of athletic performance was the race and time trial results.

Laboratory testing was being overused. We brought in elite cyclists, tested them, and found their results only above average to good; yet they were winning the Tour De France. This taught us that testing was probably a better tool to use with younger riders as a way to show them improvement. Testing helped them keep the big three of testing in check—VO2 max,
lactate threshold and economy of pedal stroke—and helped them gain a little more information about themselves. This allowed the younger riders to work more effectively with their coaches to better design training.

Lab testing is not the Holy Grail that most people had hoped it would be. I'm not against lab testing but what I tell people is that on-bike results are more meaningful. Another important issue is that the person doing the testing, the physiologist, has to have a good understanding of the sport of cycling. This is to insure that neither too much nor too little is read into the results. It is also to work with coaches and athletes within the context of an athlete's age, maturity, training history, events competed in, time of the season and a host of other real world variables.

Testing Tips

If athletes choose to have testing done, they should go to a laboratory that has a bike that can replicate the positioning of their road bike. This is a very important consideration. To arrive at the most accurate results, the bike should be electromagnetically braked as opposed to the old friction braked bikes. This leads into the capability of getting a max watt and threshold reading. The protocol used should allow for maximum performance to be gradually achieved in 12 to 18 minutes.

The tests that should be done are: VO2 max, blood lactate, efficiency and looking at VO2 at various wattages. If a VO2 is X at 200 watts, then you compare that to the mean of the whole national team at 200 watts—this will show the athlete if it costs more oxygen or less oxygen. This is an example of why correct interpretation of the data is so important to an athlete. Athletes should get something out of the testing rather than discouragement. If an athlete has a VO2 max of 75 ml and a champion has one at 85 ml, the question becomes, "Will I ever be great?" In this case, the data has to be put into context. If the athlete is only 20-years-old, has been racing for just two years and it's early in the season, s/he should not get down on him/herself because of the 10 ml difference. All three—athlete, coach and physiologist—need to be on the same page and should set aside time to review the data together to prevent the athlete from being discouraged. During this time, the three should also ask questions and plan future strategies.

Another example of why consultation is so important involves body composition. Let's say the average body composition of the women's national team is 12%, and an athlete is at 15%. Does this mean she should get down to 12%? No, because if she is already racing strong and performing well, 15% may be a healthier percent for this individual. Data has to be individualized based on each athlete.

A final consideration in testing is that tests need to be done repeatedly. This is the only way that a true picture of an athlete can be painted. A one-shot deal for VO2 max or body composition won't tell you anything by which you can really gauge your progress. Such tests should be performed pre-season, early season, late season and post-season in order to obtain relevant data. If you gather this data over several years, then you can expect a lot more consistency in its interpretation and an athlete's individual response to training and competition. Finally, these tests should be all done at the same altitude since results generated at sea level will have a different meaning in higher altitudes.

Future Considerations

In the future we'll see a combination of heart rate and power meters that measure watts. With new technology in these areas, lab tests will be taken out into the field more and more. We can now obtain an athlete's max watts and heart rate, and watts and heart rate at threshold. In addition, miniaturized VO2 units that allow for portability of self-testing are being developed. In time, the lab will come along for the ride with cyclists on the road, mountain trail or velodrome. This will offer a new level of accuracy because testing data will be gathered in true-life conditions. This will eliminate the drawback of a stationary lab bike, which is unable to move or flex the way an actual bike does.

Self Monitoring

This leads us to the history and discussion of a self-monitoring process that athletes do on their own or with a coach. Up until the advent of heart rate monitors in the early 80s, athletes didn't really have a tool to measure physiological responses to their training. With the addition of perceived exertion and heart rate information, athletes are better able to define training zones based on lab or race data. This allows for better design of training programs based on training of different energy systems or race demands.

Heart rate monitors have evolved and improved in quality over the years. Some athletes use them religiously in training. Others use them on recovery days in order to be sure they are not stressing their body too much. These cyclists are aware that for active recovery to take place, their heart rate should not exceed 120 beats a minute. Still others use the monitors while racing, putting them in their pocket and storing all the data. Then, after the race has ended, they are able to download the information to review. This helps cyclists to better understand the demands that were placed on them during the race and to review their responses to the conditions of the race. This information will greatly assist them in the design of future training and racing strategies.

Heart rate monitors are used in many ways to help athletes gain biofeedback in training and recovery. They have added
an extra sophistication to the entire training process. In the last two or three years several companies have introduced power meters that measure wattage. Now we can accurately measures watts on the road, trail and velodrome. Combined with heart rate monitors, this new tool has added supplemental sophistication to the biofeedback process. Heart rate has its limitations in sprinting and high intensity intervals—the heart doesn't keep up. But, in measuring watts we are provided instant feedback. If an athlete has to produce 300 watts during a certain interval, the meter doesn't know if s/he is going up a hill or working against or with the wind. The heart rate will be affected by all these factors and it will have a lag time. Watts are a more precise measure of workload. Heart rate has more value in the steady state aerobic values we measure.

With all these innovations, the need for testing in the lab will slowly fade away as testing will primarily be performed in the field. Heart rate monitors today are 99.9 percent accurate. The expensive models of power meters are just as accurate. As with all technology, prices will decrease and accuracy increase on the less expensive models as the demand for them grows, making this type of testing much more affordable and accessible. In addition to portable VO2 max monitors, portable lactate analyzers are in development. People are using these and they too are obtaining more sophistication.

This lab-to-field transfer is desirable because it replicates the sport to a greater degree. Measurements are taken out on the road under real environmental conditions and with the riders’ own bike. Treadmills come much closer to replicating running than indoor cycles do to cycling. Cross-country skiers have the same problem that we in cycling have. They have attempted to replicate the outdoors with a treadmill of their own, but its not snow. Testing skiers needs to be outdoors to ensure receipt of more meaningful data. The future of testing and monitoring is moving to the next level and offers some great opportunities for cyclists to advance their training at all levels.

Recovery

Recovery has many facets with nutrition, massage, and hot and cold plunges, a few examples. The importance of recovery became obvious to me in the late 80s. I was gaining feedback from athletes who were reporting: "I know I'm not putting in too many hard days in a row or too many miles on the bike.Yet I don't feel like I'm coming back the next day the way I feel I should. I'm not recovered enough."

This lead to the belief that what is important is not what athletes are doing in training but what they were doing to recover during the time between training and competitive activities. In talking to athletes, they revealed that they were paying attention to what they eat during training and right after, but little during the other 20 hours of the day. As a result, focus started to change. We began to look at refueling glycogen stores, reducing post-training competition muscle soreness, rebuilding muscles and helping protect the immune system. A lot of research was being conducted in this area.

The next challenge was to pull all of it together and apply it to cycling in a practical approach. After training, athletes were found to be dehydrated and glycogen depleted. Research said the sooner we are able to restore these two factors the more likely the athletes would achieve full nutrient recovery for training in 24 hours. The difference of being 100 percent recovered as opposed to 90 percent is significant if you want to achieve the next day's training goals. Athletes started to consume carbohydrate beverages right after rides. They also weighed themselves pre- and post ride to determine water weight loss during training and competition.

Athletes would try to return to their pre-activity weight as soon as possible by consuming fluids. This is the hydration part of the equation. The next concept to evolve was to take in protein along with carbs in their beverage right after activity. The protein was there for three reasons: one, to synergistically aid release of insulin to help with a greater uptake of carbohydrates; two, since muscles were under a lot of duress, the added protein helps reduce muscle soreness and rebuild muscles; third, protein played a part in supporting the immune system.

Based on this research, I developed a recovery beverage with a ratio of four-to-one of carbohydrate and protein grams. The amount of carbohydrate was based on body weight and intensity of activity. If it was light to moderate, our recommendation was about half a gram of carbohydrate for every pound of body weight, with 25 percent of that being the protein. If the workout was intense, this amount should be bumped up to three-quarters to one gram per pound of body weight, with 25 percent of that protein. This should be done within the first 60 minutes after activity. This nutritional strategy along with the technique of weighing-in to check hydration has become an effective one-two punch in recovery and quality training the next day.

Before this new concept, the primary post-training or competition recovery was massage. Massage is important—it provides a "passive stretch" that aids in the recovery of soft tissue such as tendons, ligaments and muscles. It has the ability to reduce swelling that takes place with certain types of high intensity exercise. And for the athletes, it's a 30- to-40-minute period of mind and body relaxation. The next evolutionary step will be to take the post one-hour recovery system and expand it to 24 hours. To ensure that recovering is adequate, athletes should be taking in three to five grams of carbohydrates per pound of body weight; three grams for a light day, four for a moderate day and five for an intense day.

How the post-activity recovery food is consumed doesn't necessarily have to be in a beverage. This is somewhat of a misconception. A bagel and piece of ham with water will work well. Beverages are simply more convenient and easier to measure and digest than solid foods.

Doping

Unfortunately, doping to some is another method of recovery and I feel that needs to be addressed. It is a part of the culture of cycling. I hate to say this, but I don't know what will break the cycle of using dope. The biggest thing out there
today is EPO, but there's also the use of growth hormones and testosterone. Use of the latter two is somewhat surprising on the surface. Why would a skinny, "gets sand kicked in his face at the beach" road racer want to take muscle-building drugs? Won't big, bulky muscles slow him down? This is a question that I get constantly. The reason is that these things aren't taken in to make a cyclist bigger, as with body builders, but to allow for better muscle recovery after hard training. As a result, cyclists are able to take on more intense training. In some studies drugs have been shown to increase the number of red blood cells. Therefore, most athletes who use these drugs do so not in the competitive season but at their highest training volume periods. When they come off they can race better. Hopefully, with more out-of-competition testing, users of these drugs will be caught.

We do have improved doping controls. There is a new test for EPO but unfortunately, newer drugs are out there that are better than EPO. We developed effective tests for anabolic steroids so athletes went to testosterone, and when a test for this was developed, use of growth hormones started. Now they have come out with a masking agent for the steroids. The harsh reality is that athletes are going to use these methods.

Drug use, testing and masking drug use is constantly evolving and will continue into the foreseeable future. The price of winning by using drugs is too high. Today's athletes are training harder and the stresses are higher. In some of their minds, use of illegal and legal aids will allow them to compete better. It is my contention that drug use to help performance and recovery occurs in a very small part of the cycling population. Hopefully, with the promotion of newer and more effective natural recovery methods—good nutrition, supplementation, antioxidants, massage and sleep—athletes will apply the use of these methods, rather than take drugs to help them race better. This may be wishful thinking, but the battle must be continued on that front.

Drug use is part of the cycling culture. During the 60s when riders in the Tour De France learned of drugs testing, they went on strike. They said, "You can't take our drugs away. The nature of this event with three weeks of stress can't be done without taking drugs!" There were stories published in the New York Times showing riders standing in line protesting. This thinking is one of the most frustrating aspects of the sport of cycling.

How can the clean athletes compete against "dirty" athletes? In my years of experience I've seen athletes change their way of thinking, in addition to their morals and ethics on this issue. The closer they got to competing at the national level and beyond, the more their thinking changed. I've never heard an athlete say, "Boy, I hope I can continue to improve so that I can get to the point where I can start taking the drugs." No one is that stupid. Sadly, they say, "I have to take this stuff in order to compete." They have been training so hard for so many years that there is the temptation to say, "Maybe I'll need to take this stuff only for a few months." But once they start down the drug road, it seldom works that way. They feel they have to do it to keep up.

What to Expect of the Future

In the future, I believe that there will be improved monitoring of cycling athletes in the field through use of better, more affordable tools. These will be used in conjunction with improved training programs and better, more educated coaches. There will be a package cyclists can use to legally enhance performance. They will have a better handle as to what's going on with their training and recovery. This control by the cyclists will allow for a greater sense of satisfaction in training and competition and will produce a greater reward for those involved. Hopefully, through better nutrition and legal ergogenic recovery methods, those few athletes who abuse drugs will forgo the use of illegal substances and join in the true sense of accomplishment.

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PUBLISHING STATEMENT:
Performance Conditioning Cycling Newsletter (ISSN 1544-242x) is published seven times a year: August/September, October/November, December/January, February, March, April/May and June/July in cooperation with the USA Cycling Federation and the National Off-Road Bicycle Association, by Performance Conditioning, Inc., Ken Kontor CAE, C.S.C.S., publisher. Subscription price $29 per year, $26 for USCF and NORBA licensed riders in the United States. Canada add $5, other countries add $8. U.S. funds only for all transactions.

NEW SUBSCRIPTIONS:
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POSTMASTER
Send address changes to: condpress@aol.com or Performance Conditioning Cycling Newsletter, P.O. Box 6835, Lincoln, NE 68506-0819.

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