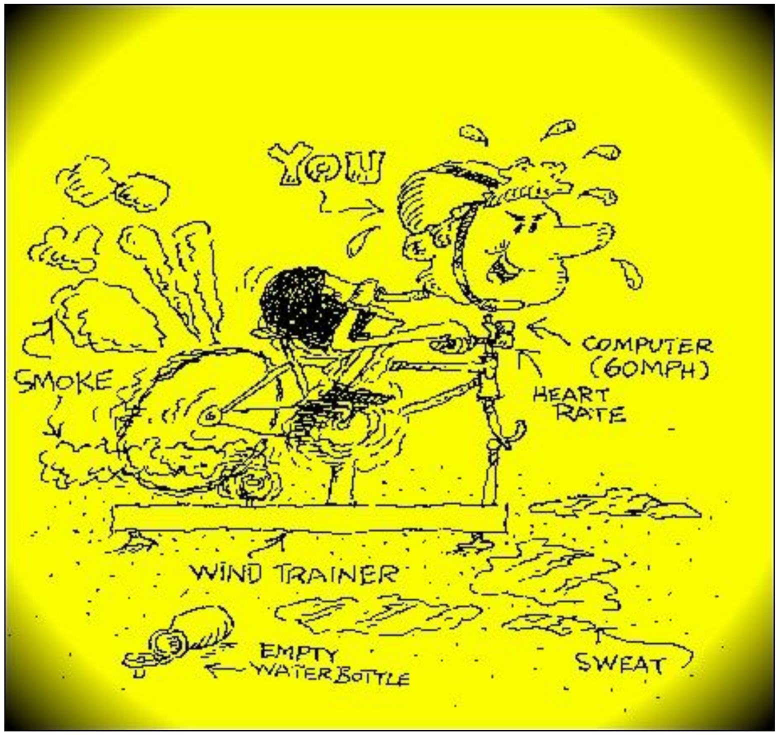

2013 (15th) Edition

Progressive Systems Training

High-Intensity Training (HIT) for Cyclists

Arnie Baker, MD

Progressive Systems Training

High-Intensity Training (HIT™) for Cyclists

Arnie Baker, MD

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Also by Arnie Baker, MD

- Altitude-Climbing-Endurance (ACE) Training for Cyclists
- Bicycling Medicine—Cycling Nutrition, Physiology and Injury Prevention and Treatment
- Bike Fit
- Nutrition for Sports
- Psychling Psychology—Mind Training for Cyclists
- Skills Training for Cyclists
- Smart Cycling—Successful Training & Racing
- Smart Coaching
- Strategy & Tactics for Cyclists
- The Essential Cyclist
- USCF: Essentials of Bicycle Training & Racing

Coach and Author

Arnie Baker, MD

Dr. Arnie Baker has been coaching since 1987. A professional, licensed USCF coach, he has coached racers to several Olympic Games, more than 120 U.S. National Championships, and 30 U.S. records. He is the National Cycling Coach for Team in Training. This endurance-training program of more than 800 coaches and 30,000 participants raises more than $80,000,000 each year for the Leukemia & Lymphoma Society.

Arnie has held a Category 1 USCF racing license. He has set eight U.S. 40-K time trial records, has won six national championships, and has won more than 200 races. An all-round racer, he was the first to medal in every championship event in his district in a single year.

Dr. Baker is a licensed physician in San Diego, California. He obtained his M.D. as well as a master's degree in surgery from McGill University, Montreal. He is a board-certified family practitioner. Before retiring to ride, coach, and write, he devoted approximately half of his medical practice to bicyclists. He has served on the fitness board of *Bicycling* magazine as a bicycling-physician consultant. He has been a medical consultant to *USA Cycling* and the *International Olympic Committee*.

Arnie has authored or co-authored 16 books and more than 1,000 articles on bicycling and bicycling-related subjects.

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I thank Gero McGuffin, who not only has helped with proofing and criticism, but with whom I have performed more than 1,000 interval workouts.

On Training

"There have now been many studies of elite performers—[in groups as diverse as] concert violinists, chess grandmasters, professional ice-skaters, mathematicians, and so forth—and the biggest difference researchers find between them and lesser performers is the amount of deliberate practice they've accumulated.

Indeed, the most important talent may be the talent for practice itself.

K. Anders Ericsson, a cognitive psychologist and expert on performance, notes that the most important role that innate factors play may be in a person's *willingness* to engage in sustained training.

He has found, for example, that top performers dislike practicing just as much as others do. (That's why, for example, athletes and musicians usually quit practicing when they retire.) But, more than others, [during their careers] they have the will to keep at it anyway."

From The Learning Curve *by Atul Gawande (As a surgical resident and staff writer for The New Yorker, in an article on the training of surgeons, The New Yorker, January 28, 2002).*

Forward

This is a book about high-intensity training for cyclists.

High-intensity training is not just for racers. Bicycle riders with a few months of riding, or perhaps 1,000 miles under their belts, can benefit from a program of higher-intensity riding.

Beginners are cautioned to approach "all-out" efforts gradually, and riders over the age of 40 or those with known medical conditions are advised to consult a physician before embarking on a high-intensity program.

Before starting interval training, all riders are advised to read the tips on the next page and principles of progression on page 92.

This book is divided into six parts.

Part 1 is an introduction to the basics of training for cyclists. This section reviews training principles, many of which are common to all sports. The workout variables of bicycle training and the components of high-end bicycle riding and racing success are presented. Heart-rate, power, and torque-based training methods are elaborated.

Part 2 reviews the principles of interval training for most cycling disciplines. Depending upon individual goals, parts of this section may or may not be relevant to individual training. This part includes many tables and graphs about interval training.

Part 3 contains practical tips to performing interval training. Hints to make your training time effective while at the same time decreasing perception of effort.

Although the principles of interval training elaborated in the second and third parts of this book can be used to tailor specific high-intensity programs to individual goals, I have outlined some programs that work for almost all riders.

Part 4 is a specific 3-month program of twice-a-week progressive workouts. Each workout is 1-1/2 to 2 hours long. These workouts are suitable for almost all levels of cyclists with base training—from beginners to professionals. The workouts form a solid high-intensity program for all types of cyclists—mountain bikers, road riders, and track racers.

Part 5 contains specific 5- and 9-week programs for peaking. Similar to the standard 3-month program, the workouts are twice-a-week and progressive. Each workout is 1-1/2 to 2 hours long.

Part 6 contains a quiz (and answers) about intervals. Those of you inclined to begin at the end, or not ask for directions, can start here. If you score 100% on the test before reading this primer, maybe you do not need to.

If you are like almost all of the several thousand riders and coaches I have trained with these principles and programs over the years, I'm know that you'll be pleased with your progress as an athlete.

Please send me an e-mail if you have suggestions for the next edition—things I have missed, things you would like to see me address, things you would like me to change. You will find contact information on my website, arniebakercycling.com.

Thank you,

Arnie Baker

Baker's Dozen HIT™ Tips

"I train for good luck!"
—Arturo Barrios[1]

1. Develop an endurance base before attempting interval work.
2. Use a long HIT™ phase (up to three months) to prepare for your competitive season.
3. Use a short HIT™ phase (up to nine weeks) to peak for one or two of your most important events or races.
4. Work under controlled conditions so that you can compare workload and performance from interval to interval or from session to session.
   a. Stationary trainer generally provides the most controlled conditions.

      On stationary trainer, perform intervals with the same resistance settings, cadence, or power outputs.

      If you control the settings of your stationary trainer (tire pressure, roller resistance, gearing) your cadence computer effectively becomes a power meter, reflecting your workload.
   b. On the road, perform intervals on similar courses or loops.
5. Work on the different fitness systems sequentially, and/or on different days.
6. Allow yourself to adapt to workloads before performing workouts at high intensity.
7. Work hard, but do not try to make every interval workout your best—it is unrealistic.
8. Pace each interval. Generally work harder throughout each interval.
9. Pace interval sessions. Within a workout, generally work each interval harder.
10. Pace periodization. During HIT™ phases, plan successive exercise sessions to adapt, build, peak, recover, and peak again.
11. In other words, work as hard as possible, at times, and try to set personal records for cadence, strength work, aerobic work, power output. However, do not try to set records more often than once every three or four sessions for a particular exercise.
12. Allow periods of recovery. In general, perform interval work no more than two or three times per week; less if racing—racing is as intense as interval work.
13. Plan for at least several months of no interval work each year.

[1] Barrios, a runner, is a former world record holder at 10,000 m (27:08.23), set on August 18, 1989). Barrios set world records at one hour (21.101 km) and 20,000 m (56:55.6). Barrios' 1991 performance makes him the first man ever to run a half-marathon distance in less than one hour.

Part 1: Training Basics

Grandescunt aucta labore[2]
—By work, all things increase and grow

Fitness derives from genetic, serendipitous, and planned events.

In other words, you are given it, you are lucky, or you work for it.

Some of us seem almost born to be fit, and respond quickly to training. Others are slower to adapt. The most important strategy in becoming an Olympic athlete might be to choose one's parents wisely; it is just not practical.

Most athletes start out as "fun" enthusiasts. Fitness is achieved, often by chance. Many athletes who do well do so because their training is sound, even if there is no overall purpose, program, or plan. Although demands may be made on the separate elements of fitness, they are not teasing out these fitness elements; they are not optimizing their genetic potential.

Finally, fitness results from planned activities. Coaches, sport scientists, nutritionists, body workers, and others combine to design, develop, and implement training programs to improve or maximize genetic potential.

This book is about some of those planned activities; specifically high-intensity training.

In other words, how and what *you* can do to get fitter!

[2] Motto of McGill University, my alma mater.

Riding Recipe

Many riders simplistically think that all you need is to be strong. There is a lot more to it. The following information places training in perspective.

Riding Requirements

The major elements of successful riding and racing can be dissected. Consider each ingredient. Train each one—the right amount at the right time. Put the ingredients together. You will go a long way toward optimizing your potential.

Some of these elements are:

- Fitness, including
  - Aerobic fitness
  - Muscle-strength fitness
  - Endurance fitness
  - Metabolic fitness
  - Anaerobic fitness
  - Power
  - Neuromuscular (e.g. leg-speed and torque) fitness
  - Neurohormonal fitness
- Nutrition, including
  - Diet
  - Body composition
  - Ergogenics
- Physical health
- Equipment
  - Bicycle fit
  - Bicycle geometry, aerodynamics, weight, and other specifications
  - Bicycle maintenance
- Strategy and tactics, including pacing and energy conservation
- Skills
  - Bike handling, including balance, proximity, descending, and cornering
- Mental attitude, goal setting, and sport psychology
- Physical health
- Recovery and overtraining

High-Intensity Training (HIT) for Cyclists is about achieving fitness. Recovery and overtraining are also discussed.

More Information

Other *ABC* (*Arnie Baker Cycling*) publications provide more information about other elements of successful riding and racing:

- Diet, body composition, and ergogenics are discussed in *Nutrition for Cyclists*.
- Equipment, in terms of bicycle positioning, is discussed in *Bike Fit*.
- Bike handling and other skills are discussed in *Skills Training for Cyclists*.
- *Strategy and Tactics* is about achieving results on event day with the fitness you already have.
- Mental attitude, goal setting, sport psychology, and goal setting are discussed in *Psychling Psychology*.
- Physical health issues are discussed in *Bicycling Medicine*.

Fitness Elements

Fitness means different things to different people. Some aspects of fitness are very specific to specific sports. Weight lifters think of fitness differently than curlers or chess players.

It is valuable to know about the elements of cycling fitness, because knowing what elements are important helps us decide how to train.

Although some aspects of fitness do have genetic limits, most athletes are limited by their training rather than by their heredity.

The elements of bicycling fitness follow.

The performance of most non-racer cycling enthusiasts—century riders, all-day riders, randonneurs, tourists—depends chiefly on the first three.

Racer success may be limited by any of the major eight fitness elements outlined below.

Types of Cycling Fitness

Many elements of cycling fitness belong to more than one type of fitness and so it is sometimes hard to tease out the fitness elements, or understand them clearly. (Consider, as an analogy, various systems on your bicycle: The cogs on your back wheel belong to the drive-train system as well as to the wheel system.)

Aerobic Fitness

The ability to use oxygen for energy production. This is important for performance in any event longer than 30 seconds. The heart, lungs, blood vessels, and muscles are all involved in the aerobic chain.

With training, the biggest changes in aerobic fitness are (1) the amount of blood the heart pumps with each beat and (2) the quantity of enzymes in muscle cells.

The amount of blood the heart pumps is a product of how much blood the heart pumps with each beat and how fast the heart beats.[3]

The lungs are usually not the limiting factor in aerobic fitness. They are very efficient in transferring oxygen from small airways to the blood. Although not the limiting factor, the athlete's perception of aerobic limitation is usually perceived to be in the lungs.

Lung power *can* be a limiting factor in the presence of disease (for example, asthma), at altitude, or at high levels of exertion in trained athletes.

The muscles are important in the aerobic chain. Fit riders extract more oxygen from the blood as it courses through the muscles than less fit riders.

As riders increase fitness, they increase the quantity of enzymes within muscles that use oxygen to metabolize carbohydrate and produce energy.[4]

---

[3] The amount of blood the heart pumps each minute (cardiac output) is the product of how much blood the heart pumps with each beat (stroke volume) and how many times the heart beats per minute (heart rate).

Typically, sedentary untrained young male adults have a cardiac output of 5 liters per minute, the product of a stroke volume of 71 milliliters and a heart rate of 70 beats per minute.

With maximum exertion, such individuals have a cardiac output of up to 20 liters per minute, the product of a stroke volume of 105 milliliters and a heart rate of 195 beats per minute.

Typically high-level aerobic young male adult athletes also have a resting cardiac output of 5 liters per minute, the product of a stroke volume of 100 milliliters and a heart rate of 50 beats per minute.

With maximum exertion, such individuals double cardiac output up to 40 liters per minute, the product of a stroke volume of 210 milliliters and a heart rate of 195 beats per minute.

Stroke volumes (and therefore cardiac outputs) for women average about 25% lower than those of men do. Gender differences are primarily due to the smaller average body size of women.

[4] The quantity of Kreb's citric acid cycle enzymes in mitochondria are more than doubled in high-end aerobic athletes vs. sedentary individuals.

VO_2 Testing

Lab Test

Aerobic fitness can be measured by a VO_2 max test. This test measures the volume (V) of oxygen (O_2) the body can use, in liters of oxygen per minute.[5] Power demand is ramped up in 10 to 50 watt increments, depending upon the protocol used. Oxygen use is measured from a formula whose terms include the total volume of air breathed and the amount of oxygen in inspired and expired air. This test is fair at predicting flatland time-trialing ability.

VO_2 max is often scaled to the rider's mass, or weight, in which case it measures the volume of oxygen used per minute per kilogram. Scaled to weight, the test is a good predictor of long, steady hill-climbing ability.

Although considered a measure of aerobic function, not muscular function, a VO_2 max test really does involve muscle mass too. Without adequate muscle mass, there is insufficient oxygen demand, and values will be low.

VO_2 can be estimated from the power achieved in graded-exercise (ramped) tests.

Arnie's formula is $VO_2 = 12 \times$ watts/kilogram + 3.3.[6]

For example: A final-stage ramped power output of 300 watts for a 60-kilogram (132-pound) athlete equates to a VO_2 of 63.3 milliliters of oxygen per kilogram per minute.

[5] Sedentary untrained young male adults typically have a VO_2 max of about 40 milliliters per kilogram per minute. High-level aerobic young male adult athletes typically double VO_2 max to about 80 milliliters per kilogram per minute.

[6] Read about the scientific reasoning for this formula in *Appendix C: Formulae*, starting on page 226.

Field Test

Simple field measures cost nothing and are as good or better at predicting performance.

VO_2 max can be estimated from climbing rate in a 5 to 10 minute test. Arnie's formula is VO_2 max = 15 x climbing rate (thousand feet/hour).[7]

For example: If you can climb 500 feet up a 6% grade in 10 minutes, that is an hourly rate of 3,000 feet per hour.

VO_2 max = 15 x 3 = 45 mL/kg/min.

This formula can often be simplified for specific climbs. For example, for my local 1.4-mile Torrey Pines climb, with 400 feet of climbing, predict VO_2 as: 360 / time in minutes.[8] An 8-minute climb equates to a VO_2 max of 45 milliliters per kilogram per minute.

Practical Points: Submax VO_2 and Training

More important as a predictor of performance is how much oxygen the body can use at submaximum levels, say at time-trial pace, or at other thresholds.

General aerobic fitness is trained at moderate exertion levels that correspond to roughly 65% to 85% of an individual's maximum heart rate.

High-level aerobic fitness is trained at exertion levels that correspond to roughly 80% to 85% of an individual's maximum heart rate. Athletes can train at such levels for up to about 120 minutes per week. Training time beyond this amount is limited by high-energy fuel—the ability to incorporate carbohydrate into muscle.

Read more about aerobic training on pages 113 and 115.

[7] Read about the scientific reasoning for this formula in *Appendix C: Formulae*, starting on page 226.

[8] No mystery here: 400 feet x 60 (minutes in an hour) x 15 / 1,000 ≈ 360.

Muscle-Strength Fitness

All the aerobic capacity in the world will not get you anywhere if you do not have the right muscles to use that energy.

What muscles do is contract, or shorten, when stimulated to do so by the nerves that supply them. They contract because of filaments of actin and myosin that form chemical/mechanical cross-bridges and move relative to one another.

The importance of sport-specific muscle strength is well known. For example, elite runners who try bicycle riding are often not very fast; same with bicyclists who try running. Sport-specific slow-twitch muscle strength is trained during specific sport training. Although weight-room work may help, more sport-specific exercises—such as hill running for runners and isolated leg training or big-gear riding for cyclists—are often better.

Broadly speaking, there are two types of muscle fibers: Fast-twitch and slow-twitch.

Short, high-power efforts are associated with fast-twitch fibers. For a given power output, the slower the cadence the higher the percentage of fast-twitch fibers recruited.

In a strict sport science sense, muscle strength refers to 1-rep maximum strength—the amount of weight that a muscle can lift, push, or pull one time. One-rep muscle strength is a function of fast-twitch muscle fibers. It is easy to measure 1-rep muscle strength in the gym, although the machines that isolate different muscle groups are not always cycling specific.

In cycling, muscle strength over a period of time, or power, is crucial. To contract repeatedly, muscles need energy. The energy may come from metabolic reactions with or without oxygen.

Reactions without oxygen (or anaerobic energy production) are characteristic of many fast-twitch muscle fibers, called glycolytic fibers. Reactions with oxygen are characteristic of slow-twitch muscle fibers. A subtype of fast-twitch muscle fibers may also use oxygen. Those fibers, which characteristically use oxygen to produce energy, are called oxidative fibers.

Although in pure track sprinting fast-twitch strength is crucial, in most cycling events slow-twitch strength is more important—but slow-twitch strength is very difficult to measure, in part because when slow-twitch fibers reach their limit, fast-twitch ones take over.

One lab test that comes closer to measuring what is important for most road cyclists (for most of us) is muscle fatigability. One way it is measured is by seeing how many repetitions can be performed at 70% of 1-rep maximum, or at a percentage of body weight.

Tests show that elite aerobic endurance athletes are generally not world-class when it comes to strength testing in the lab. Again, these measurements of primarily fast-twitch muscle strength are not relevant to the type of strength that aerobic-endurance athletes need—slow-twitch muscle strength.

Cycling muscles are trained by cycling—by just riding along. You are specifically strength training your cycling muscles when you feel them working.

Big-gear riding and climbing provide aerobic-muscle-specific work. Sprint work provides anaerobic muscle-specific work.

For the most cycling muscle-specific work, I separate out the muscle element of cycling fitness with isolated leg testing and training. In my experience, the power that one can generate with one leg riding at 60 rpm for three minutes is an excellent measure of cycling muscle fitness.

Read more about muscle-strength fitness training under *Torque-Based Training* on page 53.

Endurance

This is the ability to last. Endurance is required to get to the finish of an event.

Endurance can mean different things. Most sport science discussions about endurance concern events lasting one to three hours. Ultra riders may think of endurance as what Tour de France or Race Across America (RAAM) riders possess. However, track coaches think of pursuiters, as opposed to sprinters, as endurance riders. On the track, the ability to last 4 minutes is endurance.

Although many equate endurance with aerobic fitness, and although there is some overlap, they are not the same. It is possible to be able to perform a 40K time trial in 50 minutes, showing elite level aerobic ability and a VO_2 max over 80 mL / kg / min., yet fall apart in races over 100 miles.

Endurance for events up to a few hours in duration can be predicted by the tests for aerobic fitness described above.

Endurance in the sense of stage racing or ultra-distance events is not measured in the lab. It requires field evaluation.

For example, the best measure of your endurance for the Tour of the California Alps (a 129-mile ride with 16,000 feet of climbing) is simply how well you adapt to long hilly training rides.

Metabolic Fitness

This aspect of fitness comprises many factors. Here are some well-known elements in metabolic fitness:

Mitochondrial energy production. Mitochondria are the energy factories of the cells. They produce energy through biochemical reactions involving oxygen (for example, the Kreb's citric acid cycle). The number and function of mitochondria can be improved with training.

Energy can also be produced without oxygen (anaerobically). Chemical reactions that involve stored adenosine triphosphate (ATP) and creatine phosphate (CP) are important in producing energy anaerobically.

When work is accomplished without oxygen, lactic acid is produced. Lactic acid clearance involves the ability of the body to buffer (or temporarily neutralize) lactic acid as well as the ability of the body to metabolize (or burn) lactic acid. This involves many chemical substances and reactions in the muscles and in the blood (myoglobin, bicarbonate, and hemoglobin, to name only a few). As with the fitness elements listed above, training helps.

Some indication of metabolic function can be gained through lab studies including chemical analyses and muscle biopsies. For example, lactic acid levels in muscle or blood lactate levels can be measured with standard workloads or at threshold. Mitochondrial density can be determined in muscle biopsies. These tests are not as good as those discussed above in predicting human performance.

Anaerobic Fitness

The ability to produce work without oxygen is vital in many forms of bicycle racing. This is a combined metabolic (anaerobic) and muscle-strength (glycolytic) fitness.

Anaerobic fitness is necessary whenever attacks occur, when the pace gets super high, when the period for maximum effort is short. In fact, this is what mass start group racing is usually all about—riders do not usually get left behind until fitter riders push the pace and force them to exceed their aerobic and anaerobic limits.

The amount of work that can be performed over short periods (less than 30 seconds) can be measured in the lab or in the field. Peak power in the lab can be measured by computerized cycling ergometers in standardized Wingate tests. In the field, one can measure, for example, 200-meter sprint times.

This type of fitness is not particularly important for century rides or all-day touring. Although some anaerobic training may improve your aerobic fitness, you should rarely, if ever, be anaerobic during any part of such events.

Power

For most cyclists, power is the most important lab predictor of cycling performance. After all, it is power that gets you down the road. It is a more important predictor than VO_2 max.

Anaerobic Power

For track sprinters, maximum power in 3- to 30-second tests provides an excellent predictor of track sprinting fitness. The shorter the test, the more pure muscle strength is measured. When the test approaches 30 seconds, combined muscle fitness (glycolytic) and anaerobic metabolic fitness is measured. Again, anaerobic fitness has little importance for century riding or most-of-a-day events.

Aerobic Power

For most other riders, power at time-trial threshold is key to performance. Alternatively, maximum power on a ramped test lasting about 15 minutes. This is really a test of combined muscle-fitness (oxidative) and aerobic fitness. (There is a close correlation between power and oxygen uptake. Where they diverge, power is more important.)

Neuromuscular Fitness

The brain sends signals down the spinal cord to nerve cells that are wired to muscle cells. The functional building block of movement is the muscle motor unit: a single nerve cell in the spinal cord sends an all or none signal along its axon (wire, pathway) to specific muscle fibers—from a few to as many as several thousand.

Neuromuscular fitness is about the differential control of these nerve cells—*how often*, *how many*, and *which type* of nerve cells are stimulated.

Leg Speed

Leg speed is a neuromuscular fitness.

It is the neuromuscular fitness most often considered and described in this book.

It is *how often* nerve cells are stimulated. It is a skill. It is not strength; it is not related to aerobic or anaerobic function. The ability to respond to changes in tempo, especially in criteriums, requires the ability to move the legs quickly. Successful sprinters have excellent leg speed.

Can you hold 140 or more rpm for several minutes on a stationary trainer with low resistance? Can you spin over 200 rpm for short bursts? If so, you have good to excellent leg speed.

Although important in some specific bicycling disciplines, leg speed is of little importance to bicycle touring or most all-day riding—except that at moderate to high power levels cadences closer to 90 rpm are less fatiguing than those closer to 60 rpm.

Spin-ups (progressively increasing rpm drills) are an excellent method for improving this neuromuscular fitness.

Torque

The ability to produce (high) *torque* is also, in part, a neuromuscular fitness. It is *how many* (more) and *which type* of nerve cells (those with increasingly larger axons) are stimulated.[9]

Consider the rapid improvement that many experience when first going to a gym and starting to lift weights—improvement that occurs after just a few sessions. What has happened relatively quickly is not so much that the muscles have changed their structure but more that the brain has improved its ability to fire more motor units at once.

Such sport-specific neuromuscular fitness can be important in cycling.

Big-gear work and isolated leg (one-legged) training exercises at moderate to high power at 50 to 60 rpm help improve this neuromuscular fitness.

Economy

Neuromuscular fitness is important not only for leg speed and developing high torque, but for improving cycling *economy*.

Here we are concerned about the stopping of a nerve signal.

Imagine your right leg rotating though a clock circle. Most of your right leg power comes from pushing down or forward, between about one and five o'clock. You want to stop your nerve cells from activating your right leg push down/forward muscles before you get to the six o'clock position and return your leg back up to twelve o'clock. It is like getting the timing right in a car engine.

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[9] In physiologic terms, to synchronously fire anterior motoneurons. Typically, endurance cyclists fire asynchronously. Synchronous firing, like the rapid cyclical firing required to produce high cadence, is a skill that can be learned.

Although much has been written about a smooth pedal stroke and pulling up after pushing down, studies show that even professional cyclists do not do this.

What is important, and what economical cyclists do, is not push down on the returning (right) leg while the other (left) leg is in its power phase pushing down or forward. Or, at least, not push down too hard.

Isolated leg (one-legged) training exercises at low power (in easy gears) at about 80 rpm are an excellent method for improving this neuromuscular fitness.

Bike-Handling and Other Skills

Although bike-handling skills are often considered separately from fitness, skills can be considered a neuromuscular fitness.

Skills learning is a brain function. The execution of skills requires a brain/nerve/muscle connection.

Neurohormonal Fitness

This type of fitness is poorly understood, but important. It includes some of the following areas: Pain perception and the neurohormonal response and tolerance of training volume and intensity. How brain cells talk with one another, and how the body's hormones respond and adapt to stress.

Bicycle training not only changes neurochemistry, it may change the physical structure of the brain itself. "Extensive practice in… athletes… changes their brains as well as their bodies."[10]

Neurohormonal fitness is required to respond and adapt to training without overtraining.

Testing for neurohormonal fitness is in its infancy. We are just beginning to understand the physiological underpinnings of neurohormonal factors.

Read more about overtraining beginning on page 63.

Other Types of Fitness

Above are some of the major aspects of fitness. The list is not complete.

Much of what we know has to do with what we can measure. What is hard to measure we may ignore. For example, we rarely consider the lubrication of joints and muscle viscosity, which may be important factors in economy (the ability to produce more with less).

Gastrointestinal fitness can be crucial in endurance events. The ability to drink and eat and to digest nutrients is frequently a limiter to performance in long events. Like other fitness elements, gastrointestinal fitness can be trained.

Immunologic fitness—the resistance to disease—may also be important for cyclists.

Recovery is an important aspect of fitness, which involves not only some of the systems described above, but also nutrition and rest.

Read more about recovery on page 67.

Fitness Summary

Cycling fitness is more than just big muscles or big lungs.

Often, as stated above, it has nothing to do with either of those two factors.

By understanding cycling fitness, we will understand how to train to improve our performance.

[10] Bill Hendrick, Cox News Service, July 5, 2005.

Fitness Element	Components	Code Words	Process	Testing
Aerobic	Heart: the pump Lungs: get oxygen into blood Muscles: get oxygen out of blood	Oxygen transport	Moving oxygen from the air to muscle cells to produce energy.	VO_2 Max Submaximum oxygen consumption 4 to 6 minute interval power
Muscle Strength	Muscles	Actin and myosin cross-bridges	Chemical/mechanical linkages in muscle cells result in muscle shortening and movement.	1-rep maximum Reps at 70% of 1-rep max
Metabolic	Cells and blood	Chemical reactions	Producing energy aerobically and/or anaerobically. Neutralizing or reacting with waste products.	Blood lactate with standard loads Lactate threshold Muscle biopsy: mitochondrial density
Anaerobic	Muscles ATP and CP energy systems Lactic acid tolerance	Without oxygen	Producing short-term work without oxygen.	Peak power Wingates 5 to 30 seconds Sprint times
Power	Anaerobic and glycolytic muscle strength Aerobic and oxidative muscle strength	Work over time	Anaerobic and/or aerobic systems producing energy to fuel muscles.	Wingates, sprints Ramped tests Power at thresholds Time vs. distance at thresholds
Endurance	Aerobic endurance Muscular endurance	Ability to last	Definition problems. See text.	Power at LT Empiric, in the field
Neuromuscular	Nerve cells stimulating muscles	Skill	Rate, number, and type of nerve cell firings stimulating muscles.	RPM with set protocols
Neurohormonal	Central nervous system Endocrine system	Neurotransmitters and hormones	Psychological states: perception, overtraining, and confidence.	Uncertain

Table 1. Selected cycling fitness elements and characteristics.

Non-Fitness Elements

Body Composition

Excess fat is useless for an athlete. Being lean is important for climbing.

Males have the best combination of bicycling performance and general health at body fat levels around 10%, women at about 15%. Body fat levels up to 5% higher are still healthy levels, but performance may suffer.

Men and women whose body fat levels drop below 5% and 10% respectively may perform even better—but general health may suffer. Excessive leanness may reduce the body's natural immunity. Athletes at such low levels are subject to a number of other health concerns including osteoporosis and eating disorders.

Every excess pound slows you about 20 seconds for every hour of climbing. If you are 20 pounds overweight, a century may take an extra half hour to complete.

Diet and Ergogenics

Know how to use your diet to help you, not hurt you. What to eat, when to eat. Occasionally specific supplements or medicines can help.

For events longer than one hour, fluids and calories improve performance and reduce sense of effort.

Physical Health

You need to keep injury-free and in good physical health.

For example, for many riders backache is a problem on repeated long climbs. Some will adapt easily with a progressive climbing program. For most, back strengthening exercises are also part of our program.

Right Bike

Some bikes are specifically designed for certain types of riding and races. There are bikes better suited for road riding and others better suited for triathlon, mountain biking, or touring.

The bicycle becomes an extension of your body. Use it efficiently by optimizing your bicycle position and riding style.

You need easy gears. Late in the ride, they may not seem easy. At a minimum, most riders are advised to have a 39-tooth chainring and a 27-tooth rear cog for most centuries. A triple front chainring, compact cranks, or mountain bike cogs and derailleur are preferred for epic all-day rides such as *The Tour of the California Alps—Markleeville Death Ride.*

Lightweight equipment can help on climbs. Lightweight road racing bikes can be five pounds lighter than standard racing bicycles. As with body weight, each pound of non-rotating weight lost will save about 20 seconds for every hour of climbing. Rotating weight (wheel and pedals) saves twice as much time per pound as fat on your body or bike frame.

Aero wheels and tires with less rolling resistance can really help on flat rides. Note however that sometimes weight is increased in an aerodynamic design, and that aero wheels are often unstable when descending, especially with crosswinds.

Bicycle maintenance improves reliability and reduces mechanical friction. A clean bike is a happy bike.

Bike Handling

You need to know how to make your bicycle go exactly where you want it to go. This is important in descending, where crosswinds affect bike handling. Safe, controlled descending is a must. Be especially alert near the end of the ride when fatigue reduces your judgment and skill.

Bike handling skills are developed not only during regular riding and racing, but also by practice during specific skill and technique training sessions.

Ride Smart

Use your physical talent correctly. Use your energy at the right time with a ride plan and the parts that make up the overall plan—strategy and tactics.

Most importantly, pace your effort. Do not work too hard too early.

Most riders waste a lot of their precious energy. Efficient drafting and slip-sliding on climbs save energy when riding with groups. Avoid wasting energy with side-to-side and up-and-down motions that do not propel you and your bike forward. Make every effort count.

Sport Psychology

The mental aspects can provide the crucial difference. Motivation, confidence, the setting of realistic and attainable goals, mental rehearsal, and visualization, control of arousal and anxiety can all help you perform to potential. Attending to, understanding, and working through the psychological conflicts we all experience help resolve these frequent barriers to success.

Rest Right

It is not just training that makes us fitter; it is the recovery from training that is crucial. It is not enough to know how to ride hard. You must know how to rest and recover. How to ride easy as well as hard. How to recover to allow a peak for major competitions. How to assure proper sleep despite the logistics of organizing the rest of life, travel and other obstacles.

Read more about recovery on page 67.

The Training Curve

The way from point A to point B is not a straight line. If you do not anticipate training curves, you may become frustrated and lose motivation.

Training Is Not Linear

Consider an athlete who is at a relatively low level of fitness, point A. The athlete would like to progress to a higher level, point B.

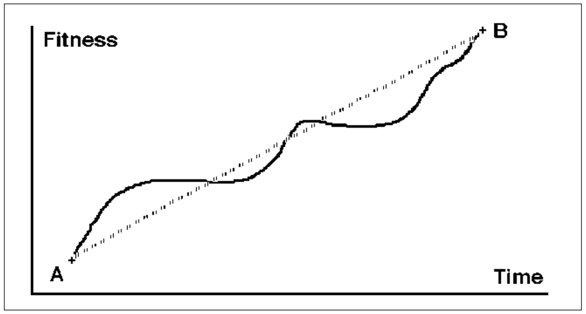

Figure 1. Training curve. Typical training curves are step-like, as in the solid line—not straight, as in the dotted line.

Training will not bring that athlete in a straight line from A to B. With the onset of training, the initial gains are great. However, as training progresses, plateaus are usually observed. Sometimes fitness even decreases.

Gains are made in spurts, in steps, rather than in a straight line.

Expect and anticipate these steps. You will be less discouraged by apparent lack of progress.

This general rule applies during relatively short cycles of weeks and months, as well as with training over long cycles of years.

It applies to many other things as well—for example, it would also be typical for a weight-loss graph.