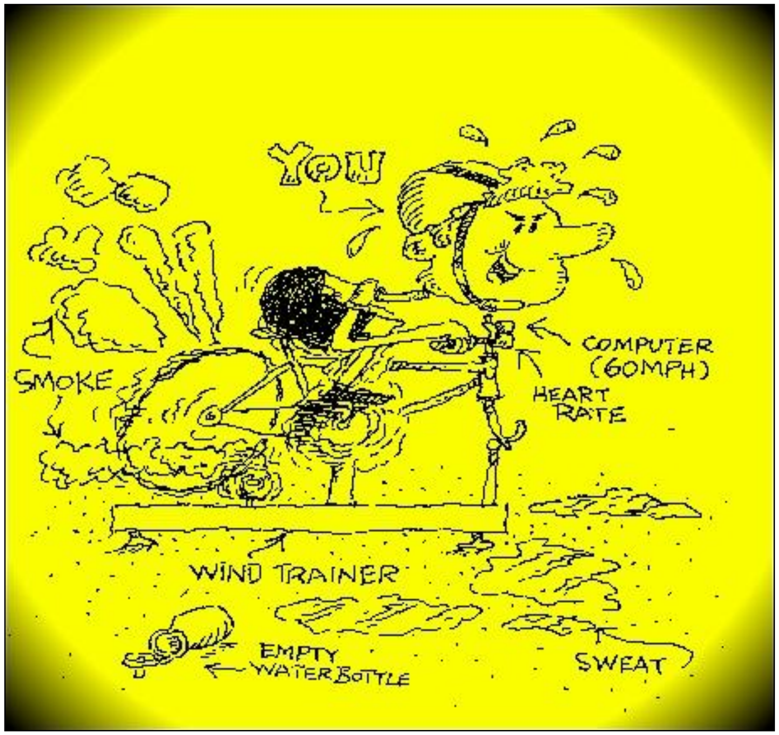

2013 (15th) Edition

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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Thank you.

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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.

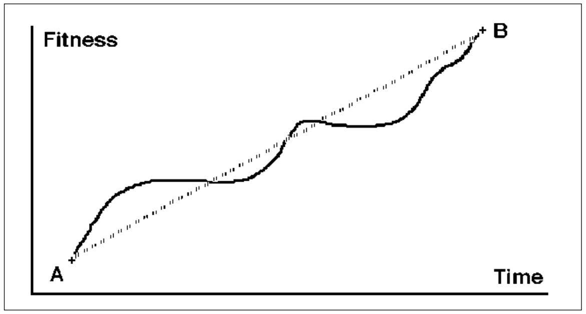

Figure 1. Training curve. Typical training curves are step-like, as in the solid line—not straight, as in the dotted line.

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.

Training Principles

Follow Your Own Program

Some of us are relatively new to riding and some of us have been racing for years. Get hints and advice from others, but remember your training program is not the same as everyone else's.

Build Up

You are at a certain place now. You may know where you want to be. Get there gradually, building up your miles and speed to reach your goals. Do not expect to get there in one big step.

Challenge Yourself

We get stronger by challenging the body. As our body adapts to training, we can continue to improve by taking on new challenges.

Be Organized

Have a program. Organize your schedule to allow you to stick to your program. Think ahead. Keep lists. It is tough to ride home from the office if you have forgotten your bicycling shoes. It is tough to ride Wednesday evening if you have forgotten to clear the decks and you have to take your child to softball practice.

Do the Same Stuff, Do Different Stuff

By repeating the same or similar workouts you will learn how hard you can go and how and when to work harder. However, changing your workouts every month or so keeps you mentally fresh and trains different aspects of fitness.

Be Flexible

It rains. You get sick. Adversity strikes. Do not brood or get uptight about it. Modify your program, if needed, and get on with your training.

Track Your Progress

Keep a record or log of how you are doing. Review it every week or two. It will let you know if you are on track and whether your program is working or needs adjustment.

Keep it Fun

Do not be a slave to your training. Keep a perspective of your overall goals. If your schedule calls for intervals but you are sick of them, do something else.

Take it Easy

It is tempting to be caught up in any program. Your program is important. However, keep it in perspective and make sure you allow proper time to recover. Avoid overtraining.

Undertraining makes it difficult to get to the finish line. Overtraining can make it impossible to get to the start line.

If you think you need recovery, you do. If you are sure you need a day of recovery, you need two!

Reward Yourself

Consider other rewards along the way. Completed the first six weeks of your training on track? Maybe reward yourself with a new pair of cycling shoes. Or with a dinner on the town to thank someone for putting up with you!

Training Triangles

When you work on a particular aspect of fitness, others will suffer.

The Problem

Here are some triangles that represent what is happening: The corners of the triangle might represent speed, endurance, and power. The triangle area represents the total amount of fitness.

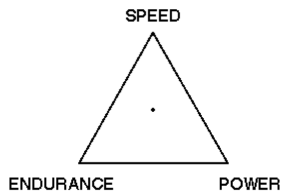

Figure 2. Base fitness triangle.

The distance from a corner to the center represents the relative amount of that fitness aspect.

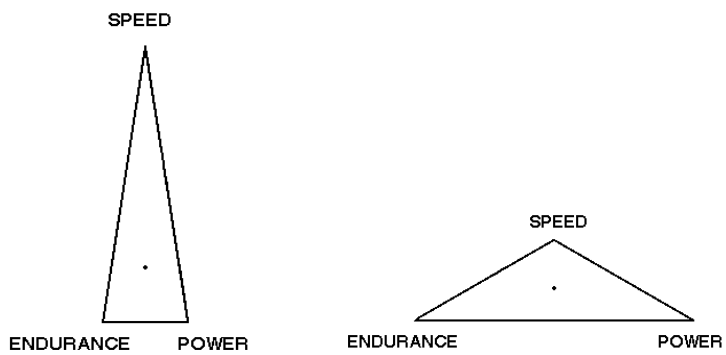

Figure 3. Specialized fitness triangles.

Work on speed—endurance and power suffer. Work on both power and endurance—speed worsens.

Alternatively, the triangles might represent hill climbing, sprinting, and time trialing ability. Work on hills—your sprinting and time trial performance worsens. Work on both time trialing and hill climbing—sprinting ability diminishes.

Training specific aspects of fitness decreases other specific aspects of fitness. How then does one improve? How are the best so good at everything?

The Solution

Consider that there are two general training concepts—general fitness and specific fitness. The answer is that fitter riders have bigger triangles.

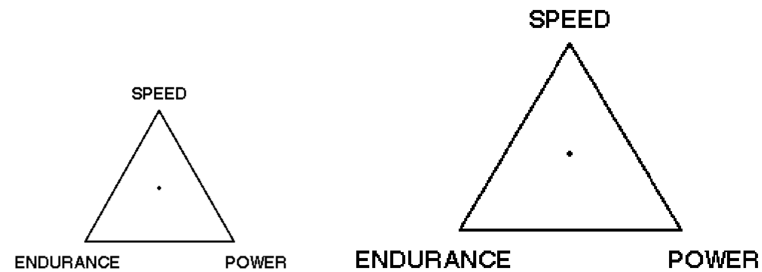

Figure 4. Increase in overall base-fitness triangle.

The best riders still experience the same triangle effect—tug on one side to make it bigger and the other sides get smaller. They are so much better overall that it seems as if they have all the types of fitness. They do not.

The best sprinters in the Tour de France do not usually time trial well. The best time trialists in the Tour do not usually sprint well. Sure they do everything better than ordinary mortals, but within the size, or area of their triangles, they still have the same situation.

Overall fitness improves with increases in quality and quantity of work the athlete performs. Many racers, as they go up through the category ranks, increase the amount of time they spend riding as well as the quality of riding through intervals, anaerobic threshold training and racing.

By the end of your program, after concentrating on climbing and riding long distances, you may not be so snappy on the flats. Alternatively, you may find that your overall fitness may have improved so much that you are better at everything.

Training Hints

The only way to get finished is to get started.

As an introduction to training, the following is a list of general hints to keep in mind during the course of your training regimen, whether you are a beginning or seasoned cyclist, or are training indoors or out. Come back to this list for a quick reference occasionally as a way of initiating a review of your overall program. The tips will help keep you on the right track.

- Get a plan, set goals, and figure out what you need to get there.
- Keep a training log.
- Use an altimeter to track feet climbed.
- Periodize your week, training differently during different sessions.
- Learn to work harder on hard days, easier on recovery days. Plan for recovery.
- Work on different aspects of fitness in different workouts.
- Climb, climb, and climb. Learn to love climbing.
- Work on aerobics, endurance, and strength.
- Work on strength with heavy gears and one-legged riding.
- Train strength by riding hills or into the wind in big gears at about 50 rpm.
- Pull and push with the same-side hand and leg when climbing.
- Establish a breathing rhythm when working hard, especially when climbing.
- Ride with riders both stronger and weaker than you are.
- Play intensity games with friends.
- Improve your riding technique and skills though practice and from coaches.
- Generally ride with relaxed, bent arms. Time trial starts and sprints are different.
- Ride with knees up-and-down or knees in. Avoid knees-out riding.[11]
- Train in different riding positions.
- Use a heart-rate monitor.
- Use a power meter.
- Wear a helmet and gloves. Keep your equipment safe and in good working order.
- Check your position on the bicycle, especially your seat height.
- Rely on food, not pills or supplements, for your nutrition.
- Maintain hydration; drink before you are thirsty.
- Keep carbohydrate solution in your water bottle.
- Optimize your weight.
- Redirect the stresses of your life.
- Have patience in your program.
- Do not try new equipment or foods for the first time on event day.
- When your group is warming up, or cooling down, ride in a smaller gear than just about everyone else to learn to spin better.
- Learn to work hard on a stationary bicycle trainer. Get together and form a class if that is what it takes.
- Practice skills such as pacelines, regularly.
- Watch good riders and how they flow without doing any more work than necessary. Try to learn from them.

[11] If you ride with knees out, you may need to raise your saddle or increase the distance between your feet using longer-axle pedals or pedal spacers.

Bicycle Workout Variables

By understanding the variables of bicycling workouts, you will understand how workout programs function to achieve different ends and be better able to design your own.

Workout Variables

The components of a bicycle workout can be broken down into six basic variables:

- Volume
- Intensity
- Cadence
- Position
- Pedal-Stroke Emphasis
- Environment

Adjust these variables depending on the goals you wish to achieve. Volume and intensity are standard workout variables that apply to almost any sport. Many riders and coaches neglect to consider that cadence, position, pedal-stroke emphasis, and environment distinguish bicycling workouts and help train different aspects of fitness.

Volume

Volume is the total amount of work performed. In other words, it is the distance or the amount of time you spend training in a given week, month, etc.

When work is performed in intervals, the length of each interval is called the duration of the interval.

Increasing volume up to about 200 miles or 15 hours per week helps improve aerobic and endurance fitness. Additional volume primarily improves endurance.

Training for long road rides requires time in the saddle to toughen the buttock tissues and adapt to riding position. Long rides, even those of minimal intensity, help train these needs.

Intensity—Introduction

Intensity is the load or speed of work performed.

Perceived exertion, heart-rate monitoring, and the less commonly available power monitoring all have roles to play in assessing work intensity.

Perceived exertion is related to many factors including breathing rate and depth, and muscle tension, burning, and heaviness.

Heart-rate monitors help measure intensity, but they, too, are imperfect. If you work on leg speed, for example, and spin flat-out as fast as you can in an easy gear for 5 minutes, your heart rate may be very high, but your power output may be only moderate.

On the other hand, if you sprint in a moderately hard gear for 20 seconds flat-out as hard as you can, your power output may be maximum, but your heart rate may not have time to “catch up” to a maximum effort.

Power measurement—traditionally available on laboratory ergometers—is also available on new-generation portable “consumer” electronic stationary trainers. Force measuring devices can also be installed at the bottom bracket, pedals, or rear wheel axle.

As glycogen energy stores are exhausted, perceived exertion is relatively high compared with heart rate, blood lactate, or power levels.

Cadence

Leg speed is another component of workouts.

Consider a rider told to work at a heart-rate intensity of 150 beats per minute for 15 minutes.

Those with a limited view of cycling fitness might think that defining intensity and duration determines the workout. It does not.

Riding at 50 rpm in a big gear at a heart rate of 150 beats per minute (bpm) trains muscular strength. Riding at 150 rpm at 150 bpm trains leg speed, a neuromuscular fitness. The workouts are quite different and give different physical results.

Some fit riders can pedal very fast—but in an easy gear, they are not necessarily working hard or going very fast.

Position

We know that the leg muscles used in cycling are different from the leg muscles used in running. That is one reason why a good runner might be a poor cyclist.

Within cycling, the muscles used in climbing are different from those muscles used in flat riding. A position component is therefore part of the workout prescription.

Climbing volume and climbing intensity are important factors in climbing fitness.

You can climb standing or seated; on the handlebar tops, on the brake hoods, or in the handlebar drops. There are important reasons to be versatile and to train in all these positions.

For steady climbing, riding with the hands on the handlebar tops is often the best way to climb. That is because the legs have more power when the hip angle is open, and aerodynamics is of minimal importance when climbing.

Pedal-Stroke Emphasis

Athletes may appear to the casual observer to be performing similar work—this is not always the case.

Consider two athletes climbing for 5 minutes at 75% of maximum heart rate, at 50 rpm, on the tops of the handlebars. The athlete who concentrates on pulling up will be performing different work than the athlete who concentrates on pushing forward or who pedals smoothly.

Training by emphasizing different parts of the pedal stroke—working specific muscle groups—defines yet another workout variable.

Environment

Workouts performed at altitude are different from workouts at sea level.

Workouts in the heat, humidity, cold, rain, or snow are different from workouts in temperate weather.

Workouts that require mental vigilance—because they are performed on roadways with potholes or cars, or workouts performed on mountain bike trails—are different from workouts performed on stationary trainers where all one’s mental energy can be focused on the bike.

Workouts performed on flat terrain are different from those where the grade is uphill or changing.

The same workout may present a different stress to the body depending upon recovery state. Sprints at the beginning of a workout are different from sprints after 5 hours of riding, though the duration and intensity may objectively be the same.

The same workout done individually may be perceived differently when performed in a group setting. Though the workload may be the same, as yet ill-defined neurohormonal factors make the environment of the workout different.

Measuring Intensity

Intensity is the load or speed of work performed. It is the "how hard" of a workout.

Perceived exertion, speed, cadence, heart-rate, power, and torque monitoring all have important roles to play in assessing work intensity. Other measures of intensity, including blood lactate and oxygen consumption, have their place in physiology labs, sport science, and experimentation, but are generally not used in training.

Measures of intensity can be used to:

1. Design training and racing programs
2. Analyze perceptions of training and racing.
3. Help keep efforts easy and hard enough.
4. Help motivation.

Measures of intensity are outlined below. More details about heart-rate, power, and torque monitoring follow the general outline.

Perceived Exertion

Athletes have always used perceived exertion to measure workout intensity.

Although objective measures of workout intensity are the most common measures used by "scientific" athletes and coaches, psychological intensity does not always correlate directly with these measures. Perceived exertion is related to many factors including breathing rate and depth, and muscle tension, burning, and heaviness.

There are a number of methods of rating perceived exertion.

The basic method, used by generations of athletes, is simply that work is easy, moderate, or hard.

Easy work is below the aerobic threshold, generally less than 65% of maximum heart rate. Moderate work is aerobic work, generally 66% to 85% of maximum heart rate. Hard work is sustained high-level aerobic work (above 80% of maximum heart rate), or anaerobic work.

Borg Scale

The most common "scientific" rating system is the Borg scale, from 6 to 20. For individuals with heart rate maximums of 200 beats per minute, the scale roughly corresponds to 1/10 of heart rate. The scale assigns descriptors, such as "somewhat hard" for value number 13.

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Table 2. Perceived exertion. Borg rating scale.

Perceived Exertion Summary

Some advantages of intensity measurement by perceived exertion are that the measure is descriptive, intuitive, and free.

The disadvantages are that the measure is subjective, and that its reliability and validity can be poor, especially in beginners. Using perceived exertion to regulate workload, it is easy to work too hard or too easy. Most athletes underestimate the intensity of their efforts.

Fatigue and/or glycogen depletion increases perceived effort relative to objective measures of intensity. Warm-up, group, and environmental changes alter the perception of perceived exertion.

For example, an exertion might be perceived as a Borg 17 on a solo training ride. In the excitement and stimulation of a race, the same power output might be perceived as a Borg 13.

Speed

Speed in miles (or kilometers) per hour has a role in objectively measuring intensity. Speed is unreliable when environmental factors such as wind or elevation change cannot be controlled or accounted for.

Speed is useful in designing programs for time trialists when intensity of effort is prescribed by pace—whether on level ground or climbs, whether 40K (25 mile) riders or 4K track racers.

Cadence

As described above, under *Bicycle Workout Variables*, page 25, cadence, or pedal revolutions per minute, may be a reflection of muscular tension or neuromuscular work.

For these kinds of efforts, cadence can be an important measure of work intensity.

Wired cadence measurement is best. Imputed or virtual, or wireless devices are generally less accurate, especially at high rpm.

Heart Rate

Heart rates are easily monitored with heart-rate monitors.

Advantages of heart rate monitors include their relative low cost ($50 for a basic model) and that they provide a quantifiable measure of intensity. They are best used in measuring aerobic intensity.

Heart rate monitoring is relatively poor in quantifying the intensity of strength and leg speed work. If you work on leg speed, for example, and spin flat-out as fast as you can in an easy gear for 5 minutes, your heart rate may be very high, but your power output may be only moderate.

On the other hand, if you sprint in a moderately hard gear for 20 seconds flat-out as hard as you can, your power output may be maximum, but your heart rate may not have time to “catch up” to a maximum effort.

Figure 5. Heart rate monitor receiver. Watch-like receiver, manufactured by Polar Electro Oy.

Monitors lag in the measurement of anaerobic work. Heart rates of more than 90% of maximum are sufficient, but not necessary, to document anaerobic work.

Read more about heart-rate monitoring on page 34.

Power

Power is the rate of work. Power measurement—traditionally available on laboratory ergometers—has been available on new-generation portable “consumer” devices for about a decade.

Some have argued that fitness, a response to training, responds more closely to power training than any other method of intensity training.

Some devices are quite valid and accurate. Some can measure changes in small fractions of a pedal stroke. Reliable units tend to be expensive ($500 to $2,000^{+}).

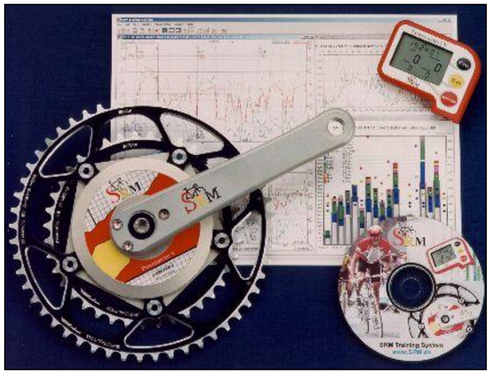

Figure 6. Crank power-measuring device. Manufactured by SRM (Schoberer Rad Messtechnik).

Power is arguably the best measure of muscular work. Power measurement provides immediate, effort sensitive feedback. Unlike speed, it is unaffected by environmental conditions such as wind or elevation change. It is objective and accurate.

Read more about power monitoring on page 39

Figure 7. Hub power-measuring device. Manufactured by PowerTap.

Torque

Torque is rotational force. Power measuring devices measure crank or wheel torque and multiply by cadence or speed to determine power.

Said differently, torque is power per pedal stroke.

Although closely related, they are not the same. Sometimes torque training is different from power training.

Read more about torque monitoring on page 53.

Blood Lactate

Blood lactate measurements, traditionally performed only in physiology labs, can be measured in the field. Portable consumer units are still generally unreliable and not valid measurements of effort.

Figure 8. Blood lactate measurement device. Manufactured by Accusport. Portable, moderately expensive, and marketed to individual athletes and coaches.

Blood lactate testing has other disadvantages. It is invasive (requires blood samples). There is a delay in the body's processing of muscle lactic acid to blood lactate, and the technology requires time to process a blood sample.

Devices are expensive ($300 to $2,000+). Each test also requires testing strips or chemical reagents that cost several dollars.

There are also more fundamental and theoretical problems with this measure of intensity. The measurement of lactate in the blood is less important, and removed, from what is going on with lactic acid production in working muscles.

When and to what degree lactic acid or blood lactate limits performance is also subject to debate.

Oxygen Uptake

Oxygen uptake can be used as a measure of intensity, but generally only in physiology labs under testing conditions. These devices are cumbersome. Oxygen update lags effort. They are poor at reflecting anaerobic work.

Figure 9. Oxygen uptake. Collecting tubes carry expired gases to a measuring device.

Oxygen uptake can be estimated from power output. (Arnie's formula: $VO_2 = 12 \times watts / kg + 3.3$. Oxygen uptake in milliliters per kilogram body mass equals power output per kilogram times twelve, plus 3.3.)

Intensity Summary

Common methods of measuring cycling intensity are summarized in Table 3.

There are many methods of subjectively or objectively measuring workout intensity. No single measure of intensity gives the full story. Using several measures gives a clear picture of effort.

Perceived effort, using informal or formal scales, is the method most commonly used. For most cyclists, heart rate monitoring is a good, objective measure of aerobic intensity. Power measurement is a relatively expensive and underused method of measuring muscular work intensity. Power measurement will probably become more popular when the price of these devices falls.

Intensity Measure	Best Use	Principle Disadvantages	Cost	Response	Learning Curve to Use	Reliability (Reproducibility)	Validity (Accuracy)
Perceived exertion	Overall perception of effort	Subjective	Free	Immediate	Moderate	Improves with experience	Improves with experience
Speed	Steady-speed event training	Unreliable in uncontrolled environments or with equipment change.	+	Immediate	Short	Good in controlled situations	Good in controlled situations
Cadence	May reflect muscular tension/work at low cadence, neuromuscular work at high cadence	Limited applicability to specific training	+	Immediate	Short	Excellent	Excellent
Heart rate	Aerobic intensity	Affected by environment and other factors. Lags anaerobic efforts. May not reflect muscular or neuromuscular work.	++	Some lag	Short	Excellent	Excellent
Power	Muscular work	Expensive	++++	Immediate	Short	Good to excellent	Variable depending on device
Torque	Muscular work	Expensive	++++	Immediate	Short	Good to excellent	Variable depending on device
Blood lactate	Anaerobic intensity	Lags effort. Repeated measurements expensive.	++++	Lag	Long	Poor to good depending on device	Poor to good depending on device
Oxygen uptake	Aerobic intensity	Limited to lab setting. Reflects only aerobic intensity. Expensive	++++	Lag	Long	Good	Good

Table 3. Intensity measures summarized.

Thermal Threshold

The human body is about 25% efficient. Said differently, roughly three-quarters of the energy used to power muscles is lost as heat.

To avoid overheating, the body must get rid of this excess heat. As the body heats, more blood flows to the skin to improve heat loss.

The body cools through evaporation, conduction, and radiation.

At low levels of intensity, relatively little heat is produced, and cooling is usually not a problem.

At high levels of exercise intensity or at moderate levels of intensity in the heat, cooling in the body can be a problem. Overheating can limit performance. Overheating can result in medical illness or death. For more information about heat illnesses, see the ABC handout *Heat & Cycling*.

At low levels of intensity, heart rate parallels work intensity and stays constant.

At high levels of intensity, or moderate levels of intensity in the heat, heart rate rises with steady effort—an effect known as cardiac drift.

These points are illustrated in Figure 10.

When heart rate levels approach steady state or time trial threshold, intensity cannot be increased.

Evaporation is the most important method of heat loss during road riding. The faster you ride on the road, the greater the wind chill and the more heat is lost. Riders often become chilled on descents. Conduction losses may be important during rain.

Many of the workouts in this book are stationary trainer workouts. Trainer workouts have many advantages, but heat accumulation can limit training effectiveness.

Use one or two fans to help evaporation keep the body cool.

A fan lowers the thermal threshold. With a fan, either work can be done more easily or more work can be performed.

Figure 10. Thermal thresholds and cardiac drift. From the top: Heart rate, green; power, yellow-black; and cadence, red. The workout on the left is performed in a 39/14 gear. The workout on the right is performed in a 55/13 gear.

The low-intensity 20-minute interval on the left is below the thermal threshold. There is no cardiac drift. Heart rate 130 beats per minute. Workload 165 watts.

The moderate-intensity 15-minute interval on the right is above the thermal threshold. There is cardiac drift. Heart rate rises from 150 to 160 beats per minute. Workload 225 watts.

Effort Correlation Table

As outlined beginning on page 27, intensity can be graded in different ways.

Many use narrative descriptors, or a zone system.

Even within objective intensity methods, such as heart rate and power, different benchmarks may be used.

For example, when heart rate is used as a measure of intensity, some use percent of maximum heart rate in grading intensity. Others use percent of various threshold heart rates, or percent of heart rate reserve (the difference between maximum and resting heart rates). Even in determining resting heart rate, methods differ. Some use resting heart rate as waking heart rate at rest, in bed. Others consider resting heart rate to be heart rate seated on the bicycle at rest.

Table 4 below summarizes the relationship between various common effort descriptors.

As summarized beginning on page 30, there are many different methods of objectively measuring workout intensity. No single measure gives the full story. For most cyclists, percent of maximum heart rate provides the easiest method of quantifying aerobic intensity.

Intensity Description	Fitness/Energy System	Common Description	% Max HR	USA Cycling Zones	% TT Pace	% Ramped Power	% TT Power	Lactate	% VO_2 Max
Subaerobic		Easy. Recovery	< 65	Zone 1—<65	< 75	< 45	< 50	1.5	<50
		Noodling							
Aerobic	Aerobic-Endurance	Moderate. Club rides	66–85	Zone 2—65–72	85-95	40-80	75	2.5–4	40–85
				Zone 3—73–80					
Threshold	Aerobic/Anaerobic	Hard. Time trials	86–92	Zone 4—84–90	100	60-85	100	4–10	75–95
	Lactic Acid Clearance								
Anaerobic, Long	Max Aerobic Power	Hard. Intervals	93–97	Zone 5—91–100	110	75^{+}	110^{+}	6–12	100
	Lactic Acid Tolerance								
Anaerobic, Short	Anaerobic—CP	Hard. Sprints	97^{+*}		125	175^{+}	200^{+}	8–20	25–40
	Anaerobic Power								

Table 4. Effort correlation table.
***If from already-high level of aerobic work. This level of heart rate is sufficient, but not necessary, to assure anaerobic work.**

Heart-Rate-Based Training

Heart-rate monitors allow you to observe your heart rate while working out. This helps training, providing immediate feedback about aerobic exercise intensity.

Why Use a Heart-Rate Monitor?

As with all measures of intensity outlined above:

- Use a heart-rate monitor to help design your training and racing programs.
- Use a heart-rate monitor to help ensure that you work according to plan. A monitor helps make sure that you work hard enough when you want to work hard. It also helps make sure that you do not work too hard on easy days.
- Use a monitor to help analyze how you feel and what happens to your body in training and in racing. Monitors do not necessarily change your training, but may help allow you to understand what is going on.
- Use a monitor to help motivation. The feedback provided is engaging for many riders.

Maximum Heart Rate

Determining maximum heart rate is the first step in developing a heart-rate training program.

Why Care About Maximum Heart Rate?

For most riders, heart-rate zones for aerobic, threshold and anaerobic work are determined from maximum heart rate.

Some coaches and athletes attempt to determine maximum heart rate a few times a year to set training intensities.

Maximum Heart Rate Defined

Maximum heart rate is the highest heart rate you can achieve.

For most riders, maximum heart rate is the highest accurate number seen on their monitor during the last year. Electromagnetic transmitters are a common source of false readings.

Individualize Your Numbers

220 minus your age, and other similar formulae are useless. The statistical average for the population is wholly unsuitable for the individual. It is like saying the average person is 5’9” tall, so all bikes should be made 55 cm.

Maximum Heart Rate Changes

Maximum heart rate is not a static or fixed number.

The unfit may not be able to achieve their genetic potential because of a lack of muscular strength or energy to work hard. Their maximum heart rate will increase as they become fitter.

Once fitness exists, maximum heart rate does not change much, but it does change. Elite athletes often have a lower maximum heart rate during their competitive seasons.

Maximum heart rate is sport- and climate-specific. Maximum heart rate is higher when vertical than when horizontal, and higher when more muscle mass is engaged. Therefore, maximum heart rate running is higher than maximum heart rate cycling, which in turn is higher than maximum heart rate swimming.

Finding Your Maximum Heart Rate

To obtain a maximum heart rate value, you need to be:

1. Rested.
2. Well warmed-up.
3. Motivated to make a maximum effort.

Why rested? Rest provides for recovery from previous exertion. With muscle fatigue/soreness or a lack of glycogen, it is not possible to produce a maximum effort.

Why a warm-up? Maximum heart rate depends upon maximum cardiovascular demand. If you are not well warmed-up, there is less blood flowing to your working muscles (the pre-capillary sphincters are not all open)—maximum effort cannot elicit maximum response.

Why motivated? Many people only see their max in a race or a test in which they are motivated. It is often difficult for riders to test their max when by themselves.

There are a number of different ways to find your maximum heart rate. Here is one way:

Warm up for at least 5 to 10 minutes. After working at a moderate pace for three minutes, increase your effort by about 10% every minute.

Cyclists on an ergometer can increase power output by about 10% each minute.

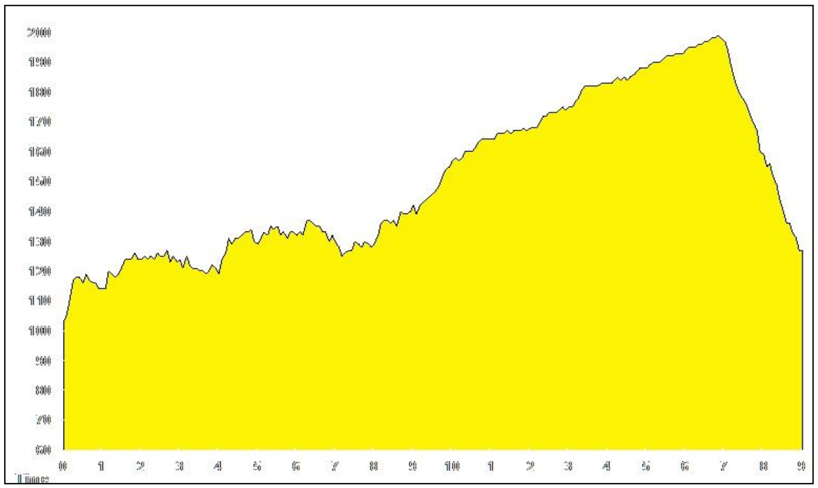

Figure 11. Ramped maximum heart-rate recording.

Cyclists riding on a velodrome or open road: Since power requirements rise between the square and the cube of speed, a 10% increase in power each minute does not mean a 10% increase in speed. Increase cadence by 3 – 5 revolutions per minute, or increase your gearing by one gear of difficulty every couple of minutes.

When you get to the point that it is extremely difficult to continue at pace, sprint as hard as you can for 30 seconds. Watch your heart monitor. This value should be close to your maximum.

Resting Heart Rate

Resting heart rate provides a tool for monitoring fitness and recovery.

Morning Resting Heart Rate

Determine resting heart rate by counting or monitoring your heart rate while not engaging in physical activity. This is usually measured first thing in the morning while lying still in bed.

Conventional wisdom states that resting heart rate is a measure of fitness and recovery. As you get fitter, your resting heart rate falls. When you are not recovered, your resting heart rate rises.

Use resting heart rate as tool in evaluation, but do not be spooked by high values: Some riders have their best performances on days that their resting heart rates are high.

Factors Affecting Resting Heart Rate

Dehydration, fever or other illness, drugs, stress, or the environment might raise resting heart rate.

For many riders, the discomfort of a full bladder, the physical activity of getting up to urinate, or the jarring of an alarm clock will raise heart rate. Resting quietly in bed for several minutes after returning from urinating or turning the alarm clock off will give a more accurate reading.

The value measured while lying flat on the back is often slightly lower than that measured while lying on the side.

Threshold Heart Rate

The heart rate that you can sustain for prolonged efforts is important in prescribing exercise training and as a measure of fitness.

Thresholds are Variable

Elite athletes can sustain 92% of their maximum heart rate in events lasting about one hour. For events longer than this, the threshold will be lower. For shorter events, the threshold will be higher.

Your Threshold

Elite athletes may sustain efforts corresponding to more than 92% of their maximum heart rate for one hour. In contrast, once beginners have the strength and endurance, they ride at about 80% of their maximum heart rate.

Since a century represents many hours of work, the level one can sustain will be considerably less. Elite racers finish a century in about 4 hours, averaging more than 80% of maximum heart rate. Beginners finish a century in more than 8 hours, averaging 65% to 75% of maximum heart rate.

Factors Affecting Heart Rate

A variety of individual and environmental factors affects heart rate. Interpreting heart rate in the context of these factors provides better insight into the meaning of heart rates.

Recovery/Fatigue State

Fatigued riders may ride at lower or higher heart rates with the same power output. For more information about this, read *Power Per Heartbeat* beginning on page 47, and *Heart Rate/Power Decoupling* on page 143.

Temperature and Humidity

Heart rates may be one beat higher for every two or three degrees above 70° F. Cold weather results in lower heart rates.

Heart-rate recordings at different temperatures are shown in Figure 12.

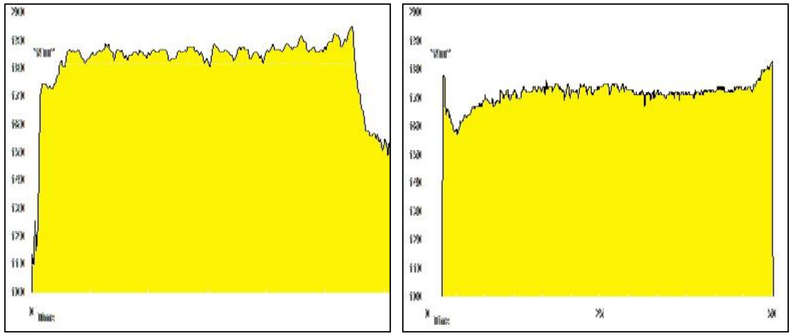

Figure 12. The same athlete performing at 90° F and 60° F. Heart rate is about 10 beats per minute higher when the temperature is 30-degrees warmer.

Altitude

Threshold and maximum heart rates are reduced about one beat for every 1,000 feet of elevation for sea-level athletes when at altitude.

Dehydration

Dehydration places increased demands upon the cardiovascular system. For a given power output, heart rates are increased.

Fitness

As most athletes become fitter, they improve their cardiovascular function and increase their sport-specific muscle mass—they are able to achieve higher maximum heart rates.

As athletes become fitter, they are able to produce more power for a given heart rate, or produce the same power with a lower heart rate.

Medications and Drugs

Drugs may decrease or increase heart rate. For example, beta-blockers like propranolol (commonly used to treat high blood pressure) can decrease heart rate and thyroid medication can increase heart rate.

Illness and Disease

Medical conditions can decrease or increase heart rate. For example, thyroid disease can decrease or increase heart rate, and illnesses with fever generally increase heart rate.

Heart-Rate Training Zones

You can establish heart-rate training zones based on percentages of your maximum heart rate.

Table 5 shows a simple zone system.

Noodling

Riding under 65% of your maximum heart rate. Easy riding. If your maximum is about 180 beats per minute, your noodling rate is under 120 beats per minute. This is recovery riding.

	% Max Heart Rate	Effort
Noodling	< 65%	Recovery, easy, “below pace”
Aerobic	66% – 85%	Group rides, “pace”
Threshold	80% – 92%	Time trials, “above pace”
Anaerobic	> 93%	Surges, jumps, intervals, sprints

Table 5. Heart-rate zones.

Aerobic Training

Your century pace is within this range.

Working between 66 and 85% of your maximum heart rate. You are training *aerobically*—“with oxygen.”

Heart-rate economy will improve: As you become fitter, you will be able to accomplish the same work at lower heart rates. Put another way, you will be able to accomplish more work at the same heart rate.

Recovery heart rate will improve: The fitter you are, the faster your heart rate will recover from hard efforts.

Threshold Training

Working between 80 and 92% of your maximum heart rate. You are at a transition between aerobic and anaerobic work. This level of work is sustainable for efforts up to an hour. Training at this level some of the time will improve your fitness for shorter and for longer events.

Threshold level will rise: New riders can commonly sustain 80% of maximum heart rate for one hour. As fitness improves, athletes can maintain levels closer to 92% of maximum heart rate.

Anaerobic Training and Racing

Heart rates 93% or more of your maximum heart rate. Efforts that you cannot keep up very long. This is very hard work. You get these redline efforts in jumps, intervals and sprints. Not the exertions needed by most commuters, weekend riders, or century riders.

Training Time Needed to Progress

As stated above, aerobic training begins at about 66% of an individual’s maximum heart rate.

To maximally train the aerobic system, riders need high-aerobic work—80% to 85% of maximum heart rate.

Once you have built a base of a thousand miles or more over a few months, you can aim to train at this intensity two or more times per week. Aim for a cumulative total of two or more hours per week.

Endurance may be improved by training at lower intensity levels, but maximal oxygen uptake may not increase.

Spending more time training at high-aerobic levels may be productive during some training phases. During these phases, riders may train at high-aerobic levels up to six hours per week.

There is a limit as to how much time riders can spend at high-aerobic levels because there is a limit to high-aerobic energy sources. Intramuscular glycogen is a limiter.

There is also a neurohormonal limiter. High volumes of high-aerobic work should not be performed routinely because of overtraining risk.

Racers need training at 86% to 92% of maximum heart rate to reach the limits of their aerobic potential. Training near this level overlaps with anaerobic training at times; this is threshold training. When training at such very-high aerobic levels, reduce the overall volume of aerobic work.

High-level aerobic training is not required for everyone. Riders are commonly able to complete successfully a hilly century without maximizing their aerobic training.

Heart-Rate Training Isn't Everything

Although heart-rate monitoring has revolutionized training for many, it is not a be-all and end-all.

While heart rate is one measure of training intensity, it is not always the appropriate way to measure intensity. It is an excellent way to measure aerobic intensity. It not the best way to measure or evaluate strength training, neuromuscular fitness (e.g. leg speed or torque), or anaerobic work.

Not everyone finds that heart-rate monitoring improves performance.

Heart Training is Specific

When you are training, you must consider the purpose of your training. Do you need to monitor heart rate? Are you training aerobically? Or are you training strength? Or anaerobic power? Or skills? Or leg speed? Or recovering?

Strength Training

You will end up stronger by having "separate" workouts or aspects of workouts for leg strength or power. The legs develop more strength in bigger gears. However, when you ride big gears, the intensity of your workout is not matched by your heart rate.

For example, riders strength train in big gears going up hills at 75% of maximum heart rate. Exertion may be similar to that perceived while riding at 85% of maximum heart rate in a smaller gear.

Unreliable for Anaerobic Work

Although heart-rate readings of 93^{+}% of your maximum are anaerobic, not all anaerobic efforts will result in heart rates in this range.

High-level aerobic work preceding anaerobic effort is generally needed to see such high heart rates.

Your heart responds to changing exercise intensity, but this response lags behind true effort. In addition, monitor readings lag true heart rate by several seconds. These lags mean that you may already be recovering before your monitor has the time to reflect true effort.

Don't Be a Slave to Your Monitor

Riding under 65% of your maximum heart rate? You are not training your heart. That may not be necessary.

Training with new aero-bars? Perhaps you want to adapt to the position, not train aerobically. You might ride an easy workout at a heart rate of 110 beats per minute

You *are* training. You are training your back muscles, your forearms, etc. You may be resting your legs, and recovering from a recent hard ride.

Recovering—that is an important part of training too!

Power-Based Training

Power is the rate of work. Power monitors provide the best measure of muscular work.

Power on a bicycle is measured in watts.

Power over time, or work, is measured in kilojoules.

Power is a measure of workout intensity. Its key features are:

- **A**bsolute, objective measure[12]
- **R**ace predictor
- **N**ot affected by confounding variables.

  Unlike speed, for example, it is unaffected by environmental conditions such as wind or elevation change.
- **I**mmediate
- **E**ffort sensitive

Power-Monitoring Benefits

- Quantify and document current and past fitness
- Compare fitness to others
- Quantify and document fitness changes that have occurred with training, overtraining, overuse injury, or traumatic injury
- Quantify total work, total work during intervals or stratify work performed at various intensities
- Quantify the demands of events
- Quantify and compare work performed with confounding variables—such as varying grades, wind conditions, temperatures, and group vs. solo riding
- Provide training intensity targets
- Encourage athletes to ride harder, or easier
- Provide training guidelines in rehabilitation
- Predict performance in training and events
- Show the decrease in ability with exposure to altitude—and the improvement that comes with acclimation[13]
- Show the decrease in ability with exposure to heat, humidity, or cold—and the improvement that comes with acclimation
- Demonstrate changes in power with hydration status or fatigue
- Suggest a check for medical causes of decreased power
- Demonstrate the aerodynamic savings of equipment
- Demonstrate the aerodynamic savings of position
- Demonstrate improved power with changes in position
- Demonstrate the value of drafting, especially to “slow learners”
- Give a measure of calories burned
- Provide immediate and reviewable feedback about pacing
- Provide athletes with biofeedback and quicker appreciation of perceived exertion
- Show that performance (power) may be fine even though feeling tired or otherwise “slow”
- Help motivation
- Help confidence

[12] Keep in mind that power meters provide an “absolute, objective measure” only within the accuracy of the device at best. For example, one study found that the coefficient of variability was about 4% for the ErgomoPro, 2% for SRM, and 1% for PowerTap. Sébastien Duc, Vincent Villerius, William Bertucci, and Frédéric Grappe. *Validity and Reproducibility of the Ergomo®Pro Power Meter Compared With the SRM and PowerTap Power Meters.* International Journal of Sports Physiology and Performance. 2:270-281. 2007.

[13] With acclimation, about 1% in TT power for every 1,000 feet up to 5,000 feet, about 2% in TT power for every 1,000 feet between 5,000 and 10,000 feet. Therefore, about a 10% decrease at 8,000 feet. Without acclimation, decrease may be twice as much, or more.

Training Load and Race Predictor

Power measurement is the gold-standard measure of absolute workload.

Power is what gets you down the road. (Wind resistance, rolling resistance, and gravity hold you back. Formulae exist for predicting performance based on power.)

Hill climbing ability correlates well to aerobic power output divided by weight. Time trialing ability correlates well to aerobic power divided by frontal area or drag. Sprinting ability correlates well to anaerobic power.

While other measures of intensity, such as perceived exertion or heart rate, can provide relative measures of individual workload intensity, they do not predict performance.

Power-based testing is easy. Testing can help evaluate the effectiveness of training. Like VO_2 max testing, power testing is valuable in predicting race performance. Unlike VO_2 max testing, power testing can be portable and need not require a physiology lab.

Immediate and Effort Sensitive

The first thing most riders notice is that power readings change dramatically and immediately even in the course of what might have been thought of as hard steady efforts.

Heart rate is a physiologically smoothed function. Riders used to looking at heart rate values know that if they surge or relax somewhat during the course of a time trial, heart rate may change only a few beats. As Figure 13 shows, power changes may be striking.

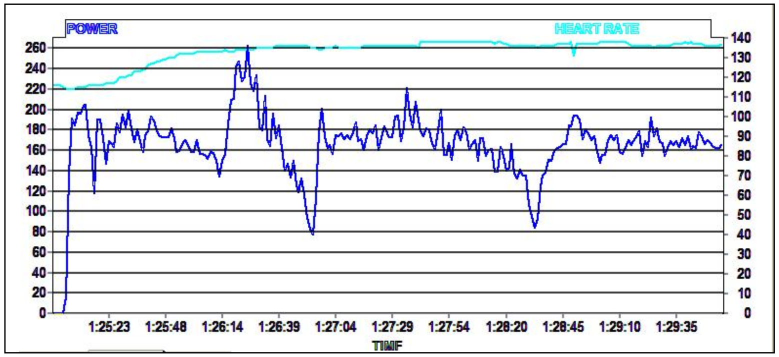

Figure 13. Dramatic change in power, little change in heart rate. Power, blue, bottom; heart rate, turquoise, top. Five-minute climb. Heart rate rises and stays high. Power output varies from 80 to 260 watts.

Devices

Power measurement—traditionally available on laboratory ergometers—has been available on new- generation portable consumer devices for more than a decade.

Durability was initially a problem for some units. This has improved.

Electronic stationary trainers generally measure power as the rear wheel turns a resistance device.

Force-measuring devices that can be installed at the pedals, crank, bottom bracket, chain, or rear wheel axle are available.

These allow riders to measure power on the road, trail, or track.

Figure 14. Stationary trainer power-measuring device. Manufactured by CompuTrainer.

Figure 15. Hub power-measuring device. PowerTap manufactured by CycleOps.

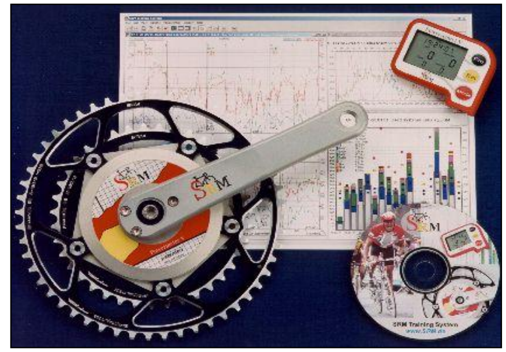

Figure 16. Crank power-measuring device. Manufactured by SRM (Schoberer Rad Messtechnik).

Some devices may add up to half a pound in weight and so fractionally worsen uphill performance.

Some devices that purport to measure power output do not—they impute it from speed, gradient, and rider weight. Such units are useful in that they provide a measure of relative workload intensity under identical conditions—for example, climbing a steady grade with no wind.

Measurement Location

To evaluate workload, you ideally want to measure power at the pedal.

The further away from the pedal you measure, the greater the mechanical power losses.

For example, you would expect power at the pedal to be greater than power measured in turn at the crank, the bottom bracket, the chain, and the rear wheel.

Although such power losses may amount to as much as 10%, they are generally less.

Accounting for such losses may be important in evaluating the same athlete on different devices, or in comparing different athletes on different devices.

Overall Validity and Reliability

Some devices give quite valid (or accurate) readings. Accurate units tend to be expensive (\$500 to \$2,000^{+}).

Some devices may give consistent values with the same workload—though the absolute values may not be accurate. In other words, they give repeatable results but are not calibrated correctly.

Such units can provide valuable information about relative training intensity during workouts for an individual, but are not useful in estimating absolute fitness relative to others.

Response to Peaks

Power output varies considerably at different points in the pedal stroke. Some devices can measure changes in small fractions of a pedal stroke.

Power measuring devices smooth this measurement to give useable averages.

Power measuring units have an easier time measuring steady-state values than peaks.

Some devices smooth or lag so much that they miss the peak outputs of surges or sprints.

Some devices allow the user to choose the degree of smoothing. This useful function shows peaks with minimal smoothing; it gives insight into overall-ride power output, including pacing, with more smoothing.

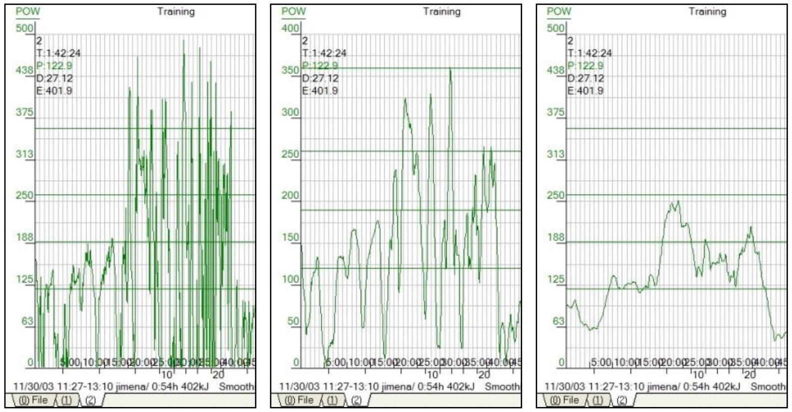

Figure 17. Smoothing. Minimal, moderate, and major smoothing of the same watts recording.

Total Work

Training hours and mileage are commonly used as measures of training volume. Total work may be a better measure of training stress.

Power is the rate of performing work. Many devices can compute the work accomplished over a period of time. This is commonly reported in kilojoules.

A joule is one watt of power for one second. There are 3,600 seconds in an hour. One kilojoule equals 1,000 joules. Therefore, averaging 100 watts of power for one hour yields 360 kilojoules of work.

Figure 24 on page 47 shows an SRM-brand crank-measuring power report that includes total work.

Calories Used

Rule of Thumb—Close Enough

Since a kilojoule equals 0.24 calories,[14] and since the body is about 24% efficient in converting energy to muscular work, kilojoules of work provide a good estimate of calories burned.

That is to say if your total ride work is 1,200 kilojoules, you have also burned about 1,200 calories in producing that work.

More Precise

For most riders, the body is closer to 22% efficient, about 10% less than the 24% quoted above. If your total ride work is 1,200 kilojoules, you have burned about 10% more calories, or about 1,320 calories.

[14] Technically one kilojoule equals 0.24 *kilo*calories. A scientific kilocalorie is popularly referred to as a calorie.

Three Ways to Use Power

Riders and coaches use power meters in three general ways:

1. During a workout
2. Download and analysis of a single workout
3. Analysis of multiple downloads

"Want to make a room full of coaches burst out laughing? Make a joke about not downloading files or (gasp!) not reviewing them. Power-meter software is critical for taking full advantage of the big picture that power data paints."

–Frank Overton, VeloNews, Vol. 35, No. 1 January 2, 2006.

Power During Efforts

This is what most riders and coaches initially examine.

What power can be sustained during a climb, time trial, or other interval?

What happens during racing? What kinds of efforts are required? Are those efforts simulated in training?

Determination is made crudely while riding, or more precisely with computer software of downloads.

Watts Per Kilogram

Just as absolute heart rate is of limited importance for most riders (percentage of maximum heart rate is a more useful statistic), absolute power output is less relevant than power per unit of mass, that is, watts per kilogram. (Metric units are used more frequently for this statistic, although some use watts per pound. A kilogram equals 2.2 pounds.)

A 90-kilogram (200-pound) rider will generate roughly twice the power of a 45-kilogram (100-pound) rider to ascend at the same speed. Watts/kilogram (pounds) will be roughly the same.

Pacing

Power monitoring provides a much better measure of pacing performance than heart rate. A declining heart rate usually indicates declining power. However, heart rate may remain high, or even increase, though power declines, as Figure 18 shows.

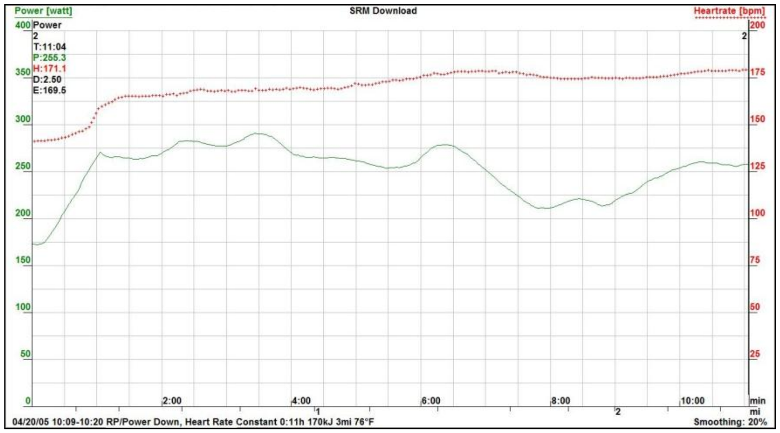

Figure 18. Pacing: Power is a better pacing indicator. Heart rate, red, above. Power, green, below. During this 10-minute effort, heart rate rises and stays up. Power of 260 watts is not held, and falls after a few minutes.

Power in Different Positions

Within limits, power is generally greater the more open the hip angle and the greater the leg extension. However, a high saddle position compromises leg speed.

Time trialists often prefer a high-saddle position that allows a more open hip angle. Power when riding bent over on aerobars is lower than when upright. Aerodynamics more than compensates for this power loss. Remember, in flat-terrain time trialing, power per frontal area/drag coefficient is a better performance predictor than power per mass (watts per kilogram).

Since most riders cannot calculate their frontal area and do not have access to wind-tunnel testing, power is not the most helpful measure of performance. Elapsed time, speed, or cadence in a specified gear on a controlled course provides a better indicator in assessing the relative effectiveness of time-trial positions.

Power vs. Time

The shorter the interval, the more average power can be generated for the interval.

Figure 19 shows how values rapidly decline from short, pure anaerobic efforts to a slow decline for aerobic work.

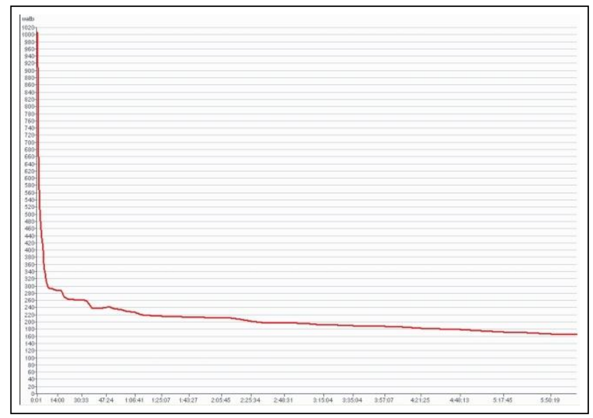

Figure 19. Power declines as the work interval lengthens. From Coggan.[15]

Power Ranges for Athletes

Riders of different abilities have substantially different power outputs.

This is in contrast to the percentage of maximum heart rate at which riders can time trial—this value is similar for men and women, young and old, beginning racers and professionals.

For example, most riders are able to complete 3- to 5-minute intervals at 90% of maximum heart rate. Beginners may perform these intervals at 100 watts. Professionals at 500 watts.

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[15] Coggan, Andrew. "The Science of Exercise and the Art of Coaching," a slide show given September 15, 2003.

Power range standards for elite riders, stratified by age and sex, are available.

Values based on athletes I have coached are listed in the appendix starting on page 224. Values according to Andrew Coggan are graphed in Figure 20.

Power Profiling

Relative to their overall ability, strong sprinters put out relatively more power for short periods of time than relatively strong time trialists.

Power Output in Watts Per Kilogram

	Men			
	5 s	1 min	5 min	20 min
World Champion/World Record Holder	23.50	11.50	7.60	6.62
	23.16	11.35	7.46	6.50
	22.82	11.20	7.33	6.38
	22.48	11.05	7.19	6.26
World Class	22.14	10.90	7.06	6.14
	21.80	10.75	6.92	6.02
	21.46	10.60	6.79	5.91
	21.12	10.45	6.65	5.79
UCI Div. I/II Pro	20.78	10.30	6.52	5.67
	20.44	10.15	6.38	5.55
	20.10	10.00	6.25	5.43
	19.76	9.85	6.11	5.31
UCI Div. III pro	19.42	9.70	5.97	5.19
	19.08	9.55	5.84	5.07
	18.74	9.40	5.70	4.95
	18.40	9.25	5.57	4.84
Cat. 1	18.06	9.10	5.43	4.72
	17.72	8.95	5.30	4.60
	17.38	8.80	5.16	4.48
	17.04	8.65	5.03	4.36
Cat. 2	16.70	8.50	4.89	4.24
	16.36	8.35	4.75	4.12
	16.02	8.20	4.62	4.00
	15.68	8.05	4.48	3.88
Cat. 3	15.34	7.90	4.35	3.76
	15.00	7.75	4.21	3.64
	14.66	7.60	4.08	3.53
	14.32	7.45	3.94	3.41
Cat. 4	13.98	7.30	3.81	3.29
	13.64	7.15	3.67	3.17
	13.30	7.00	3.53	3.05
	12.96	6.85	3.40	2.93
Cat. 5	12.62	6.70	3.26	2.81
	12.28	6.55	3.13	2.69
	11.94	6.40	2.99	2.57
	11.60	6.25	2.86	2.46
Untrained	11.26	6.10	2.72	2.34
	10.92	5.95	2.59	2.22
	10.58	5.80	2.45	2.10
	10.24	5.65	2.32	1.98
	9.90	5.50	2.18	1.86

Figure 20. Power profiling from Coggan, "Cat 3 rider with amazing sprint." Power outputs are standardized across categories for intervals of different length. Results highlighted in red for a Category 3 male racer. A strong sprinter puts out relatively more power for short periods of time relative to category, as does this rider with a Pro-level sprint.

Work Time at Different Power Levels

Just as users of heart rate monitors are used to looking at time spent in different heart rate zones, power meter programs can give the same information.

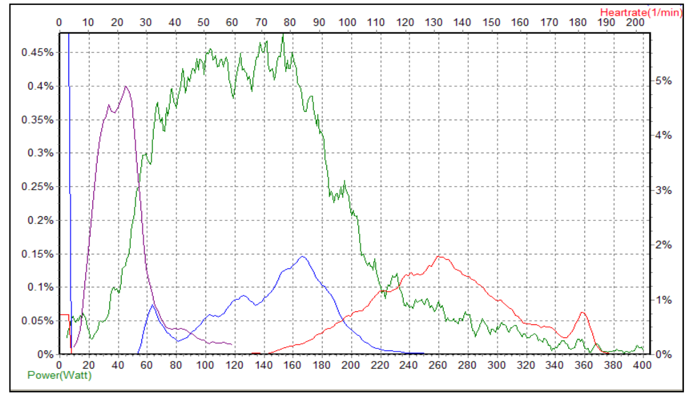


Figure 21. SRM statistics of an endurance ride of a professional mountain biker. This report displays the percentage of ride time spent at different power outputs, heart rates, and cadences.

However, training time in specific power zones only tells part of the story. Training at 300 watts for 15 minutes continuously is different from training at 300 watts for three minutes five times.

Some programs use three-dimensional displays to illustrate this.

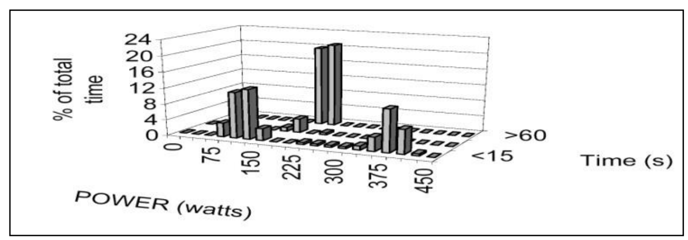


Figure 22. Three dimensional frequency distribution histogram of power output. From Coggan, "Training and racing using a power meter: an introduction."

Surges

Although steady pacing is important during time trials, mass start racing often demands surges.

Surges are physiologically demanding.

It is precisely because surges are demanding that winning riders are often aggressive in initiating and responding to attacks. Those that do not have enough fitness can't respond or tire quickly if they do.

In races, you want to make all the surges you need to, but not more than necessary.

Power programs can allow you to examine your training and racing for the quality and quantity of surges—either manually or automatically.

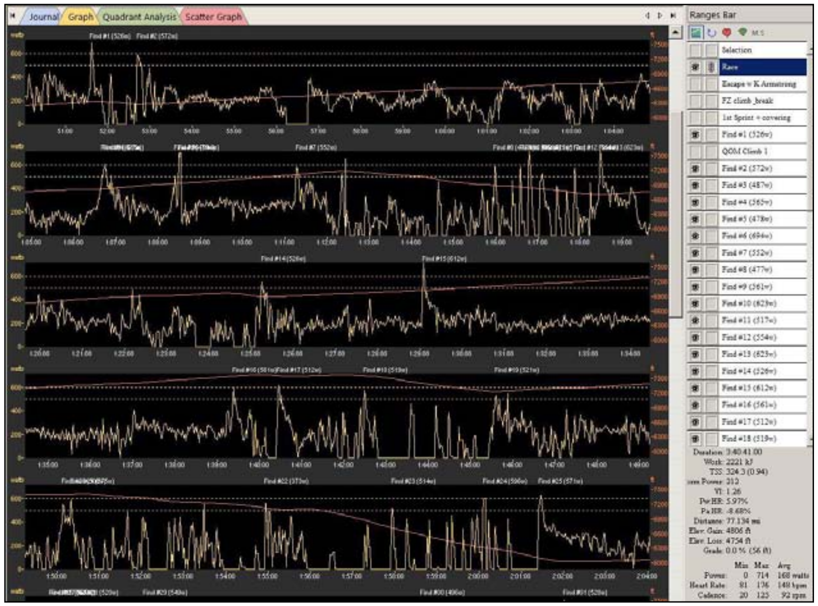


Figure 23. Partial multi-line power and altitude download of an elite women road racer. Power, yellow; altitude, red. Using the *fast find* function of TrainingPeaks WKO+ 3.0 software, 25 surges of more than 500 watts are found in this roughly one hour of racing.

Power Per Heartbeat,
Power at Fixed Heart Rate

Some power-based computer programs can compute how heart rate relates to power, the heart-rate response to increasing power demands.

There are two components: the intercept and the slope. The intercept represents the heart rate when no power is being generated. The slope represents the incremental change in heart rate with incremental change in power.

Figure 24 shows an SRM report that estimates the heart rate change with each incremental one-watt increase in power. Dividing this value into one estimates the power output gain for every one-beat increase in heart rate.

The SRM program can also compute how much power is generated at a specific heart rate—say 150 beats per minute.

Changes Between Workouts

Over time, this information can help give a measure of conditioning and evaluate the effectiveness of training. As fitness improves, under similar conditions (fatigue/recovery, nutritional, environmental), more power can be generated at a given heart rate.

Among the many physiologic explanations for this training effect:

1. The heart pumps more blood with each beat.
2. The muscles extract more oxygen from the blood.
3. The muscles store more glycogen.

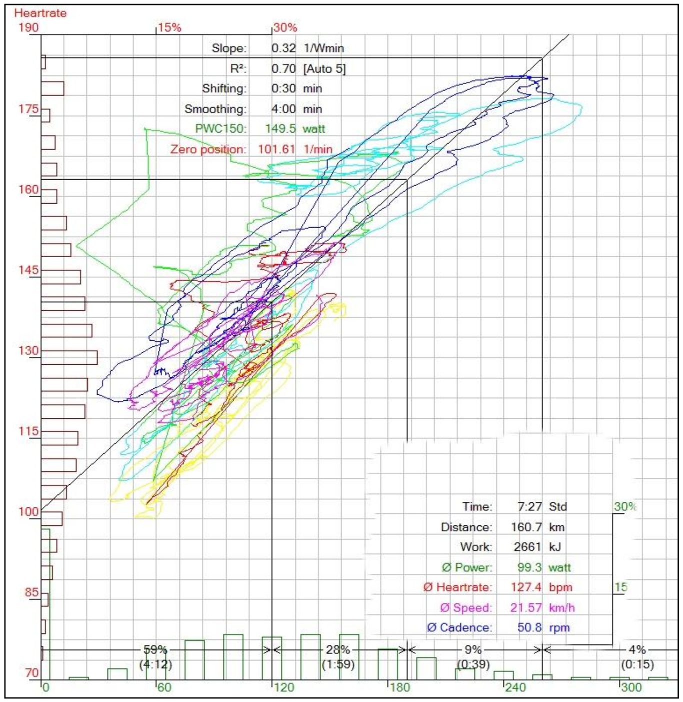


Figure 24. SRM analysis of an endurance ride of a professional mountain biker. The X-axis is power; the Y-axis is heart rate.

The program displays the metrics on the graph: This 7-hour 27-minute ride covered a distance of 160.7 kilometers. Total work was 2,661 kilojoules. Average power was 99.3 watts, average heart rate 127 beats per minute, average speed 21.57 kilometers per hour, average cadence 50.8 rpm.

Power at a heart rate of 150 beats per minute was 149.5 watts.

The Y-intercept is the heart rate when no power is being applied. This gives an estimate of the "resting" heart rate on the bike. In this case, the value is 101.6 beats per minute.

The slope of the regression line allows one to estimate how watts are related to heart rate. In this case, the slope is 0.32. This means that heart rate rises 0.32 beats for every one-watt increase in power. Said differently, for every one-beat increase in heart rate over "resting," 3.1 additional watts are generated.

Power Per Heartbeat Changes: Decoupling

Changes During a Ride

Within a session, changes in power per heartbeat may occur. Some programs report this as aerobic decoupling.

Aerobic decoupling is a fractional percentage: the numerator is the difference in power per heartbeat between the first and last halves of the recording; the denominator is the first half power per heartbeat).[16]

For example, if the first-half average power is 200 watts and the average heart rate is 160, and the second-half average power is 175 and the average heart rate is 150, then the first half power per heartbeat is 1.25 and the second half heartbeat is 1.16.

The difference is 1.25 – 1.16 = 0.09, and aerobic decoupling is 0.09 / 1.25 = 7.2%.

Figure 25 illustrates decoupling.

Aerobic decoupling occurs for many reasons:

- With dehydration, the amount of blood pumped with each beat is reduced. To maintain power, heart rate increases to maintain cardiac output (power per heartbeat declines).
- In hot conditions, more blood flows to the skin to assist cooling. To maintain power, heart rate increases to provide the same blood flow to the muscles and additional blood flow to the skin (power per heartbeat declines).
- With glycogen depletion, the percentage of fat fuel use rises. Fat metabolism is less efficient. Fat metabolism requires more oxygen to produce the same power.

  To provide increased oxygen, heart rate increases relative to power (power per heartbeat declines).
- At lower power outputs, the percent of fat use relative to carbohydrate use is higher. As power declines, heart rate increases relative to power (power per heartbeat declines).

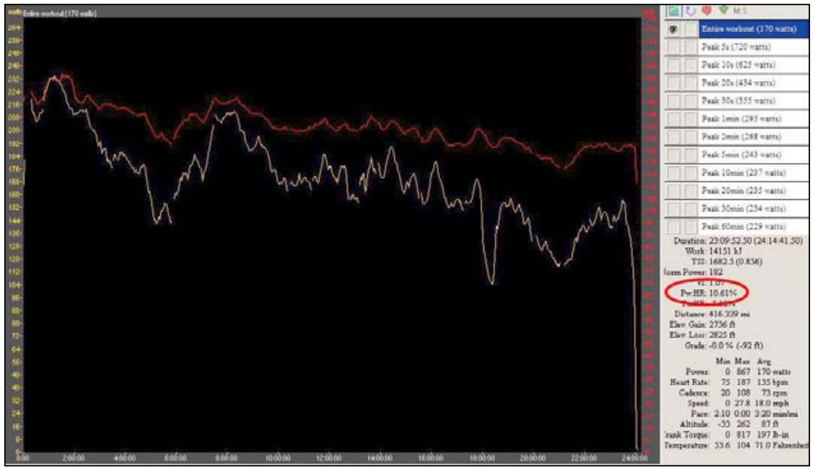


Figure 25. Decoupling. 24-hour endurance road event. Power, yellow; heart rate, red. The event started at 6:00 PM, in the desert. Night temperatures were in the 50s (°F); afternoon temperatures exceeded 100°F.

As the event progresses, both power and heart rate decline. Power declines relatively more than heart rate.

Decoupling reported as 10.61% (circled in red on right).

One might think that dehydration, heat, glycogen depletion, and fatigue—all of which were present—contributed to this decoupling. One might be wrong: see the text.

- As fatigue sets in, in a given gear, a relatively higher percentage of fast-twitch fibers are recruited. Fast-twitch fibers use more oxygen to produce the same power. [17] Heart rate increases relative to power (power per heartbeat declines).
- Cycling at a lower rpm also recruits more fast-twitch fibers. Working in the opposite efficiency direction, there is a power cost in moving the legs—cycling with no power to the pedal. The faster the rpm, the more the legs move, the greater this cost.

  When glycogen is exhausted, the balance may result in heart rate increases relative to power (power per heartbeat declines).

[16] The Golden Cheetah program (http://goldencheetah.org/) reports *Aerobic Decoupling*. The TrainingPeaks WKO+ program reports *Pw:HR*.

[17] Coyle EF, Sidossis LS, Horowitz JF, Beltz JD (1992). *Cycling efficiency is related to the percentage of type I muscle fibers.* Med Sci Sports Exerc. 24(7):782-8.

- However, when glycogen is plentiful, cycling at a lower rpm increases the use of glycogen relatively more than the recruitment of fast-twitch fibers. Again, glycogen metabolism is more efficient that fat metabolism.

  Now the reduced non-propulsive power cost of moving the legs works in the same efficient direction: heart rate decreases relative to power (power per heartbeat increases).[18]

Gross vs. Delta Aerobic Decoupling

Unless otherwise specified, aerobic decoupling refers to *gross* decoupling that reflects the change in the *total* power-per-heartbeat ratio between the first and second halves of a ride. Gross decoupling does not account for the heartbeats that do not contribute to power production (the non-propulsive heartbeats, the heartbeats that are required when the rider is coasting on the bicycle, the "resting" heartbeats required for basic metabolism).

Delta decoupling is the change in *incremental* power per heartbeat ratio between the first and second halves of a ride.[19] To compute delta decoupling, include only the heartbeats that are contributing to power production (subtract the "resting" heartbeats).

Currently available programs are inadequate or misleading:

- The TrainingPeaks and Golden Cheetah programs report gross decoupling, they do not report delta decoupling.
- The SRM program, as shown on page 47, will analyze and report the power at a heart rate of 150 bpm. It gives no direct numerical value to decoupling. As discussed above, the SRM analysis Y-intercept represents the heart rate when no power is being generated.

[18] Ahlquist LE, Bassett DR Jr, Sufit R, Nagle FJ, Thomas DP (1992). *The effect of pedaling frequency on glycogen depletion rates in type I and type II quadriceps muscle fibers during submaximal cycling exercise.* Biodynamics Laboratory, University of Wisconsin, Madison 53706. Eur J Appl Physiol Occup Physiol. 65(4):360-4.

[19] I define and consider gross and delta aerobic decoupling as Sidossis et al did in defining gross and delta mechanical efficiency: Sidossis, LS, Horowitz JF, Coyle, EF. *Load and Velocity of Contraction Influence Gross and Delta Mechanical Efficiency.* Int J Sports Med 13: 407-411. 1992.

Where power averages are different between the first and second halves of a ride, *all* of the reported gross decoupling may be due to different power averages rather than due to the factors discussed in the bulleted list above.

For example, greater than 10% gross decoupling is shown in Figure 25. When delta decoupling is computed, assuming a no-watts heart rate of 75, the value shrinks to 0%.

Table 6 displays the underlying values for Figure 25, and shows that when changes in power between the first and second halves are taken into account, decoupling vanishes.

Workout	1st Half	2nd Half	Decoupling
Power (average)	186.6	152.8	
Heart rate (average)	139.5	127.8	
Heartbeats producing power (delta)	64.5	52.8	
Power/heart rate, decoupling (gross)	1.34	1.20	10.6%
Power/heartbeat, decoupling (delta)	2.89	2.89	0.0%

Table 6. Correcting for differences in power often accounts for differences in power per heartbeat. The underlying data from Figure 25 is presented.

The corrected delta heartbeats values are heart rate minus 75 bpm, representing the heart rate with no work performed.

Decoupling is the difference between the first and second half power-per-heartbeat ratios divided by the first power-per-heartbeat ratio.

Said differently, unless power or heart rate averages are the same in the first and second halves of a ride, looking at gross decoupling (rather than delta decoupling), may be a waste of time.

Training: Power-Based Intervals

As stated above, the shorter the interval, the more average power can be generated for the interval.

The maximum average amount of power that can be generated for a given time is sometimes termed critical power (CP). For example, the maximum average amount of power than can be generated for 60 minutes is sometimes referred to as CP60.[20]

Power ranges for ABC high-intensity workouts are large—given the great variations in individual fitness.

One goal of training is to increase the power that can be generated for any specific length interval. This is illustrated in Figure 26.

Basing Training Intensity on Threshold Power

One method of prescribing power-based interval intensity is to target values based on threshold power.

Using threshold power to determine training intensities for various length intervals means that multiple testing sessions for different interval lengths are not necessary.

There is a physiologic basis for this approach.

For example, some coaches target power outputs for 3- to 5-minute intervals at 110% of 10-mile or 20-kilometer average time-trial power.

If you can time trial for 10 miles or 20 kilometers at 300 watts, you might target to perform 3- to 5-minute intervals at 330 watts.

This approach has pitfalls, especially for intervals of one minute or less.

Although power level multipliers for intervals of specific durations have population averages or norms, these do not apply to the individual.

[20] This definition of critical power has been popularized by Joe and Dirk Friel. Others define critical power as power at VO_2 max or maximum ramped power.

Consider that although the average bicycle racer may be able to average 4 times more power for a 5-second interval than for a 10-mile time trial, the sprint specialist will have a higher multiple.

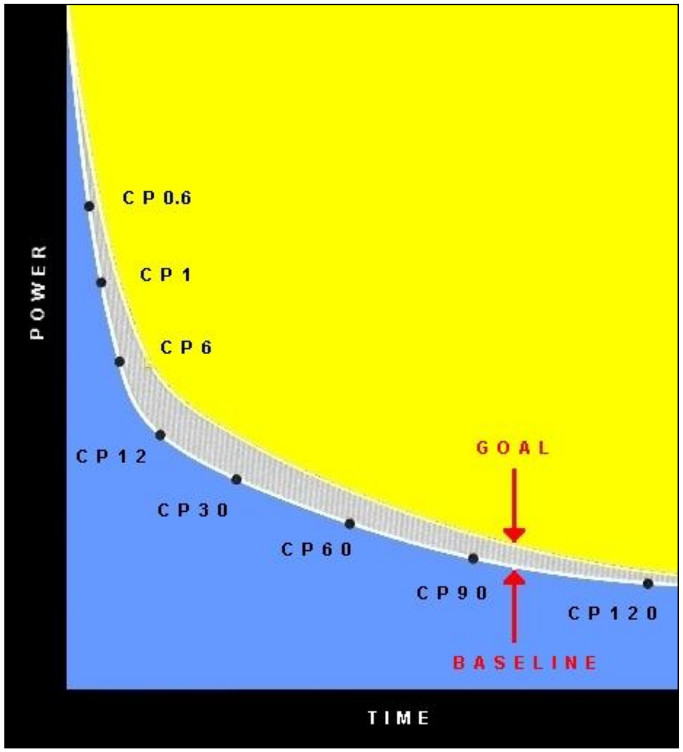


Figure 26. Power vs. time. Effective training increases the maximum average (critical) power that can be generated from baseline (lower curve) to a higher one—in this case for CP120, a two-hour effort. Illustration from PowerTap.

Basing Training Intensity on Max Ramped Power

This is a variation of the above. Similar to a VO_2 max test, this is a progressive test until exhaustion.

After a warm-up, power is ramped up—say 20 watts per minute—until failure.

Percentages of maximum ramped power are used to determine training intensity levels.

This method has pitfalls similar to basing intensity on threshold power.

Basing Intervals on Trial and Error

In some ways, basing training intensity on threshold or max-ramped power is like basing weight-room workouts on 1-rep max. Many strength and conditioning coaches specify, for example, 10-rep workouts at say 80% of 1-rep max. Determining 1-rep max generally is for experienced lifters only.

From a practical point of view, many who strength train simply determine, though trial and error over a few sessions, how much they can lift for 10 repetitions.

In the same way, adapting to 3- to 5-minute intervals over several sessions, and determining watts goals through trial and error is just as valid a method as arbitrarily trying to work out at 110% of time-trial threshold.

As alluded to above, determining anaerobic efforts based on time-trial threshold is fraught with error, as riders have more or less anaerobic vs. aerobic power.

Although testing critical power for many interval lengths has theoretical merit, in practice as fitness increases, these values change.

In practice, riders must determine their anaerobic power targets through trial and error, based in part on number of repetitions, recovery interval length, and coaching philosophy.

Targeting power based on trial and error has another advantage: It is simpler than performing multiple, repeated tests and calculating percentages.

Predicting Individual Form

Manipulation of training volume and intensity is used to improve training and peak for events.

Software can be used to analyze past training load and predict an individual's form.

Such software requires using a power meter on every ride. Cross training confounds the program.

An intuitive rider or coach can often predict performance as well as such programs, or better.

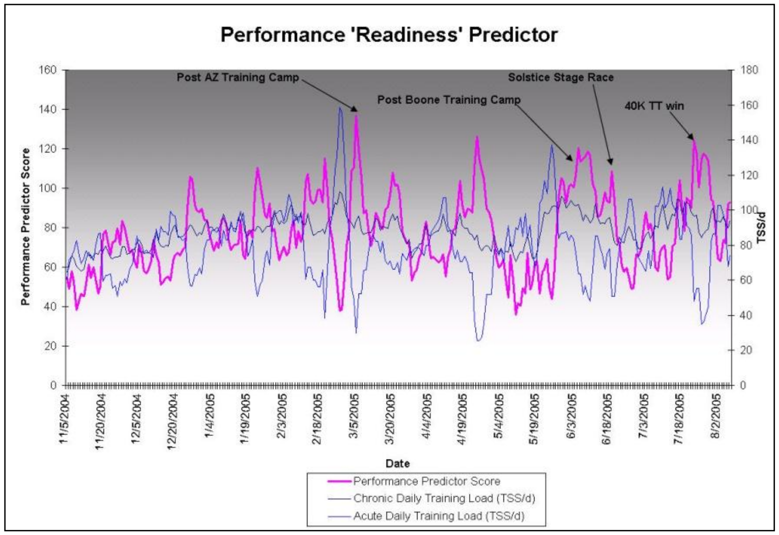


Figure 27. Predicting form. CyclingPeaks secondary software graph of acute and chronic training loads and performance prediction.[21]

Power vs. Other Intensity Measures

As shown in Figure 28 and Figure 29, under controlled circumstances, other measures of intensity can give the same, similar, or additional information.

[21] From a public posting from Scott Thor accessed August 8, 2005 at: http://www.scottthor.com/modules.php?op=modload&name=News&file=article&sid=110&mode=thread&order=0&thold=0

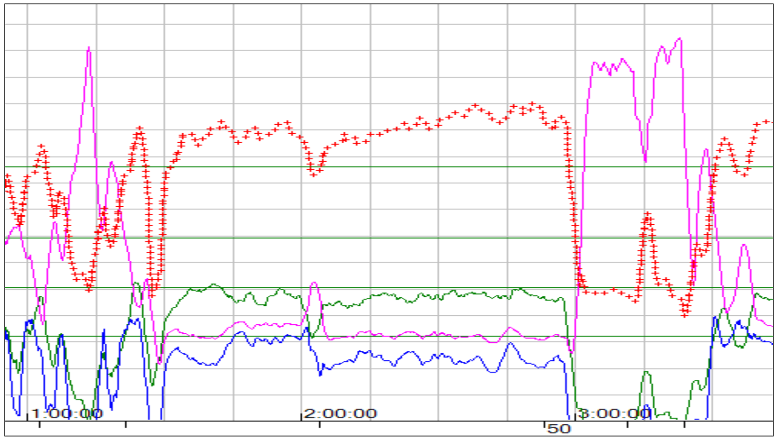


Figure 28. On a single-speed bicycle, cadence, speed, heart rate, and power roughly parallel one another. From the top: Heart rate, red; power, green; speed, pink; and cadence, blue.

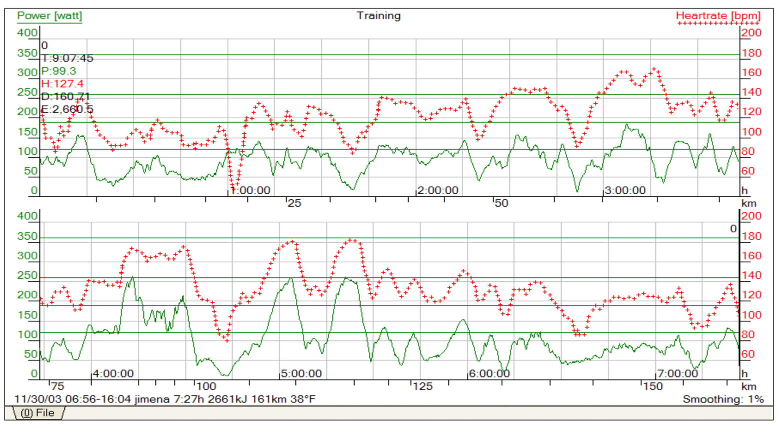


Figure 29. On a geared bicycle, heart rate and power roughly parallel one another. As heart rate lags power, power is a more sensitive immediate indicator of effort. Heart rate, red; power, green.

Summary

- Power-measuring devices provide an immediate indication of absolute workload.
- Watts per kilogram is generally more useful than absolute power.
- Power-based testing is useful. Like other measures of fitness, it is contextual, most accurate under controlled conditions.
- Power-based training can be effective in training many fitness systems.
- Unless one knows at what percentage of possible power one is riding, power does not provide a measure of relative individual exercise effort.
- In practice, I use power-measuring devices to evaluate current fitness, estimate what is possible, and to help motivation and pacing.
- I generally fall back to the oldest methods of measuring intensity—perceived exertion and instinct—in determining how much work to perform.

Torque-Based Training

Key Points

- Torque is rotational force.
- Torque is power per pedal stroke.
- Cyclists need it; training improves it.
- Isolated leg training (one-legged riding) is an excellent method of torque training.

Discover Torque

With one hand on a brake, to prevent you from moving, stand with one leg on one crank, with the crank at 6 o'clock.

There is no torque, because there is no force applied to the crank to turn it.

Again with one hand on a brake, stand with one leg on one crank, with the crank at 9 o'clock. Now there is torque, because there is a rotating force to turn the crank; but there is no power, because the cranks are not moving and you are not going anywhere.


Figure 30 and Figure 31. Stationary demonstration of torque. On the left, with the left crank at 6 o'clock, there is no rotational force, and hence no torque. On the right, with the left crank near 9 o'clock, there is crank torque—here a maximum of this rider's body weight X crank length, 135 pounds X 6.7 inches, or about 900 pound-inches.

Torque can be measured at the crank and at the wheel.

If you measure crank torque, the force standing on one crank will be the same regardless of gear.

If you measure wheel torque, the torque will be higher in an easier gear. (For the same wheel torque, crank torque will be higher in a harder gear.)

Cyclists Use Torque

1. Power (crank torque times rpm) is what gets you down the road. Power results from muscular-strength and aerobic factors. Although simplistic and not entirely accurate, it may help to think of torque as the muscular-strength factor.
2. Whenever steady-state power output is high, at least moderate torque must be produced.
3. Torque helps provide acceleration. Cyclists commonly must produce high crank torque levels to sprint or to respond to surges and attacks.

   Crank torque numbers are much higher than wheel torque numbers when sprinting in a big gear.
4. Cyclists also must produce high torque levels when undergeared—a common problem when facing steep inclines, even with professional cyclists.

   Crank torque numbers are close to wheel torque numbers when climbing close to a 1:1 gear.

   Many rides and races commonly have steep climbing pitches. Although many cyclists commonly "gut" it out, wise cyclists with easy gears who can maintain higher cadences are at strategic and physiological advantage.

   For example: amateurs are often undergeared on hilly centuries; few pros have adequate gearing for the 22% sections up Fillmore Street in the San Francisco Grand Prix or the 24% sections of the Alto de l'Angliru in the Vuelta a España.

Figure 32. Few professional cyclists have adequate gearing to optimize crank torque (and power) on Fillmore Street's 22% grade (San Francisco Grand Prix).

Basic Physics

- Force is mass multiplied by acceleration.
- Torque is rotational force. It is generally measured in pound-inches (or inch-pounds) on a bicycle.[22]
- Power is force multiplied by speed (velocity), or torque multiplied by angular velocity.
- Most power-measuring devices measure torque, either at the crank or at the wheel.
- Power is determined by crank torque multiplied by rpm (cadence) or wheel torque multiplied by speed. Power is generally measured in watts.
- Work, or power for a period of time, is generally measured in kilojoules.

[22] Pound-inches (inch-pounds) is a common English-system measurement. Pound-inches and inch-pounds are used interchangeably. TrainingPeaks software uses pound-inches. CycleOps software uses inch-pounds. Newton-meters in a common Metric-system measurement. One pound-inch equals 8.9 Newton-meters.

Torque vs. Power

Power-measuring bicycle computers, by definition, always display power. Although most measure torque and work, not all devices display these values on bicycle-mounted displays or on computer downloads.

Torque is power per pedal stroke.

Power meters may measure torque at the crank or at the wheel hub.

Although the SRM measures crank torque, it does not display it with its software. Secondary programs, such as those available from TrainingPeaks,[23] allow SRM crank torque to be displayed.

The PowerTap measures wheel torque, not crank torque, to calculate power. (Perhaps the PowerTap should be called the TorqueTap.) Again, secondary programs, such as those available from TrainingPeaks, allow PowerTap crank torque to be displayed.

Convert Wheel Torque to Crank Torque

With simple mathematics, one can convert crank and wheel torques: Crank torque = wheel torque x (chainring teeth / cog teeth).

Tip: Remember, crank torque is always greater than wheel torque, except with very easy gears—where chainring teeth are less than cog teeth—used for steep climbs to reduce torque.

If you ride at 235 watts with a cadence of 50, your crank torque will be double the torque you produce at 235 watts and a cadence of 100 rpm.

For example, at a cadence of 50 rpm you might be producing 400 pound-inches of torque at the crank. At a cadence of 100 rpm, you might be producing 200 pound-inches of torque.

In the example above, for the same power, regardless of gear, wheel torque would be the same, perhaps about 100 pound-inches.

Said differently, if wheel torque is 100 pound-inches in a 52/13 gear, crank torque will be 400 pound-inches.

[23] http://home.trainingpeaks.com/products-desktop/wko.aspx

Convert Power/Cadence to Crank Torque

Torque is power per pedal stroke.

- To convert watts per pedal stroke to pound-inches, multiply by 85.[24]
- To convert watts per pedal stroke to newton-meters, multiply by 9.6 (or about 10).

Longer Cranks Mean More Torque

With the crank at 9 o'clock, crank torque is leg force, in pounds, multiplied by crank length in inches.

A 170-millimeter crank is 170 **/** 25.4 = 6.7 inches. If one leg pushes down on a 170-mm crank at 9 o'clock with 30 pounds of force, roughly 200 pound-inches of crank torque are generated.

For a 180-millimeter crank, roughly 210 pound-inches of torque are generated.

For a given leg force, you can apply more torque with longer cranks, but not necessarily more power—since your legs must travel farther, in larger circles, to complete one revolution.

Handlebars Needed

If average crank torque is 400 pound-inches, each leg is contributing about 200 pound-inches of crank torque, pushing with about 30 pounds of force, on average, throughout the pedal stroke.

Torque is developed mostly on the downstroke; torque peaks on the downstroke may be several multiples of the average torque for the complete stroke.

[24] Torque (newton-meters)= Power (watts) **/** angular velocity (radians/second).
One newton-meter = 0.7376 foot-pounds
= 8.85 pound-inches
Cadence (rpm) = 60 **/** 2π radians/second
Therefore, power per pedal stroke units:
8.85 x 60 / 2π = 85

It is no wonder, with 400 pound-inches of crank torque, riders need to stabilize themselves with their hands on the handlebars to prevent themselves from being pushed up off the saddle.

Torque Changes with Speed, "Road Feel"

Stationary Trainers

In any given gear, on stationary trainers with "good road feel" and on level ground, increases in cadence (or speed) demand both more torque and power. (In a given gear, speed will increase linearly with cadence.)

The increase in power comes both from increasing cadence (speed) and from increasing torque.[25]

This is demonstrated in Figure 33 and Figure 34.

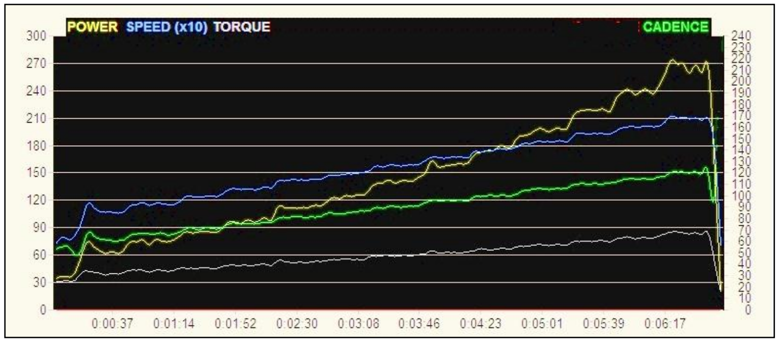
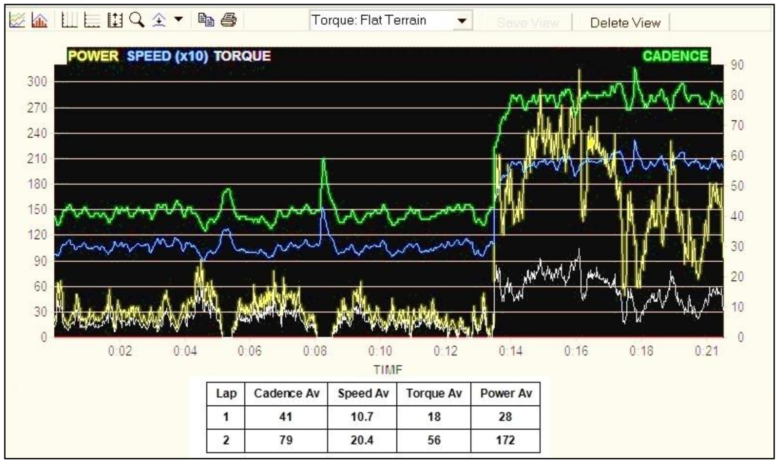


Figure 33. Torque on stationary trainer. On the left, from the top: Speed, blue; cadence, green; power, yellow; and wheel torque, grey.

Power is the product of wheel torque and speed. Power demands increase exponentially on "good road feel" stationary trainers.

Here cadence increases from 60 to 120 rpm, wheel torque increases from 40 to 80 pound-inches, speed increases from 10 to 20 mph, and power requirements increase from 60 to 260 watts.

[25] Technical detail: Riding on level ground, aerodynamic power requirements are cubed for a doubling of speed. Since most, but not all power requirements derive from aerodynamic resistance, the real world power requirements are between a square and cube function.



Lap	Cadence Av	Speed Av	Torque Av	Power Av
1	41	10.7	18	28
2	79	20.4	56	172

Figure 34. Torque on a mostly flat road. On the left, from the top: Cadence, green; speed, blue; power, yellow; and wheel torque, grey.

Two 2.5-mile laps at controlled cadence (speed) in a 53/16, riding hands on handlebar tops.

First lap, about 14 minutes; second lap about 7 minutes. Modest winds.

Average cadence about doubles, from 41 to 79 rpm; speed about doubles from 10.7 to 20.4 mph; wheel torque more than triples from 18 to 56 pound-inches; and power requirements increase a little more than six-fold, from 28 to 172 watts.

Rollers

Rollers have limited intensity-training applications, because they do not allow changing torque. In any given gear, even though cadence, and therefore speed may double, torque requirements change hardly at all (due only to minimal changes in wheel aerodynamic resistance and rolling resistance).

This is demonstrated in Figure 35.

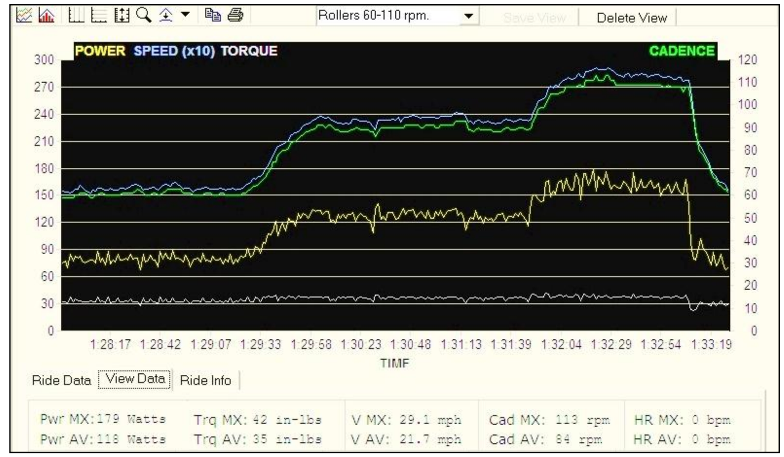


Figure 35. Torque on rollers. From the top: Speed, blue; cadence, green; power, yellow; and wheel torque, grey.

Torque requirements remain close to constant with changes in cadence or speed. The figure shows, in a 53/16 gear, cadences of 60, 90, and 110 rpm.

Average wheel torque is 35 pound-inches; maximum torque is 42 pound-inches.

Changing power demands reflect changing cadence or speed.

Climbing

On steep climbs without appreciable air or road resistance, power requirements are directly proportional to speed, and hence cadence.

In a given gear, an increase in cadence increases power demands without increasing torque demands.

This is demonstrated in Figure 36.

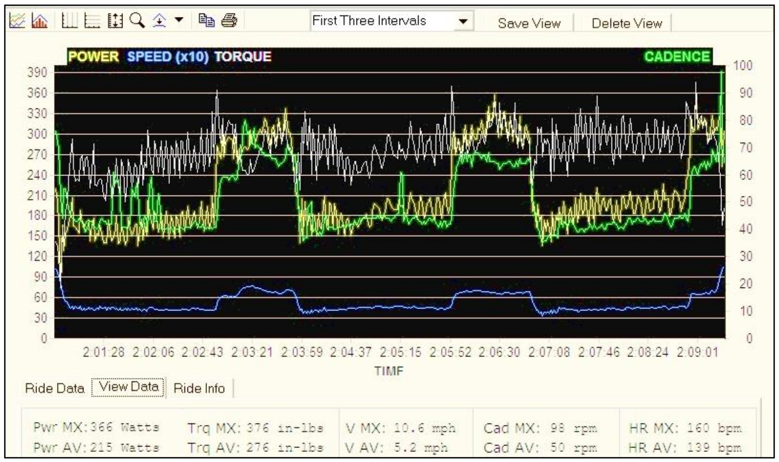


Figure 36. Torque on climbs. From the top: Wheel torque, grey; cadence, green; power, yellow; and speed, blue.

Climbing a steady, steep grade, in a given gear, increasing rpm increases power, but not torque.

Average wheel torque is 276 pound-inches; maximum torque is 376 pound-inches. 36/27 gear. Average crank torque calculated at 368 pound-inches, or 184 pound-inches for each leg.

To reduce torque, shift to an easier gear.

Guardsman Pass, near Park City, Utah. 12% grade, 9,000 feet. One-minute intervals, with a two-minute rest.

Gears Optimize Torque

Producing power, using energy, is fatiguing no matter how it is done. Increased torque means more fast-twitch fiber recruitment and is more muscularly fatiguing. Decreased torque for the same power (higher cadence) comes at a higher aerobic cost.

Think of a weight lifter trying to maximize the amount of weight she can squat in one minute. Perhaps her 1-rep max, the most she can lift one time, is 100 pounds.

- If our lifter tries to squat 90 pounds, after just a couple of repetitions, she will be fatigued and stop. The total weight she will have lifted in one minute will be 180 pounds.
- If our lifter tries to squat just one pound, she will not fatigue, but she may have the time to squat only 50 times in one minute. The total weight she will have lifted in one minute will be 50 pounds.
- The maximum amount of weight that can be squatted in one minute will come from an intermediate value. For example, our lifter may be able to squat 60 pounds 40 times for a total one-minute lift volume of 2,400 pounds.

In humans, as in mechanical engines, maximum power output does not occur with maximum torque. All engines have an optimal operating rpm range.

Of course, you know this, in a different context. Picture climbing a hill in a group, near your limit, in a 39/23 gear. Your rear derailleur cable snaps. Now you are in a 39/12. You push harder on the pedals, your torque increases, but your rpm drops, your power goes down, and you are left behind.

Think of a motorcycle engine: It may develop maximum torque at 5,000 rpm but maximal power at 6,500 rpm.

Think of a car: At too low rpm, an engine will lug. The car will have trouble producing power and may stall. Over-revving is also a problem. If car engines work at too high rpm, economy decreases, parts are subject to early fatigue, engines will overheat, and optimal power will not be produced.

At bicycle cadences <60 rpm and high torque, the power that can be produced is less than that which can be produced at cadences between 80 and 100. At some point above 100 rpm, the aerobic cost for the same power output is too high to compensate for the lower torque.

Cyclists may perceive that they are working harder if torque is greater. Since power production may be more at higher cadences and lower torque, some athletes misjudge what is most productive for them.

Without cadence, speed, or power computers, riders may feel that they are most effective and at their limit climbing a hill in a 39/17 at a cadence of 50 rpm. With a bicycle computer, they may find that their sense of effort is lower and their speed more than 15% higher in a 39/19 at 65 rpm, and almost 30% faster in a 39/21 at a cadence of 80 rpm.

Muscle Fatigue and Glycogen Use

For a given power output, greater torque and muscle tension is associated with increased glycogen use, more muscle fatigue, and microscopic muscle damage.[26]

Although this is useful in training (training with more torque can improve muscle strength), using greater torque during a particular training day or race reduces reserves for later in the same ride or race.

Glycogen is compartmentalized in slow- and fast-twitch muscle fibers, with the vast majority being stored in slow-twitch muscle fibers. Said differently, fast-twitch power is a scarce commodity.

Since fast-twitch fibers can be used as anaerobic back-up to supply power when aerobic muscle power is inadequate, it makes strategic sense to use slow-twitch fibers as much as possible and conserve fast-twitch fibers for strategic need.

In practical terms, this explains the cycling adages: “Spin up hills to save your legs,” and “Save your legs, not your gears.”

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[26] Ahlquist LE, Bassett DR Jr, Sufit R, Nagle FJ, Thomas DP (1992). *The effect of pedaling frequency on glycogen depletion rates in type I and type II quadriceps muscle fibers during submaximal cycling exercise.* Biodynamics Laboratory, University of Wisconsin, Madison 53706. Eur J Appl Physiol Occup Physiol. 65(4):360-4. On 2 separate days, eight men cycled for 30 min at approximately 85% of individual aerobic capacity at pedaling frequencies of either 50 or 100 rev.min-1. The glycogen decrease found:

	50 rpm:	100 rpm:	P
Type I fibers:	46% decrease	35% decrease	NS
Type II fibers:	49% decrease	33% decrease	<0.05

Cycling at the same metabolic cost at 50 rather than 100 rev.min-1 results in greater type II fiber glycogen depletion.

Torque Training

Training at higher torques improves muscle strength, and the ability to produce high torque.

You are strength training your cycling muscles when you feel them working.

You know you are producing high torque while seated when the force of your pedaling requires you to use your hands on the handlebars to stabilize your body to prevent your legs from pushing your buttocks off the saddle.

Practically speaking, cycling-specific slow-twitch (endurance) muscle strength can be built with big-gear, low-cadence riding at moderate power outputs and relatively low heart rates. (Say 10-minute intervals at 80% of time trial power, 75% of maximum heart rate, and cadences of about 50.) Such intervals will be at higher torques but lower power than maximum steady-state climbing power intervals of the same duration.

Cycling-specific fast-twitch (anaerobic, sprint) muscle strength can be built with big-gear, low cadence riding at near all-out power for 5 to 15 seconds, as demonstrated in Figure 37 and Figure 38.

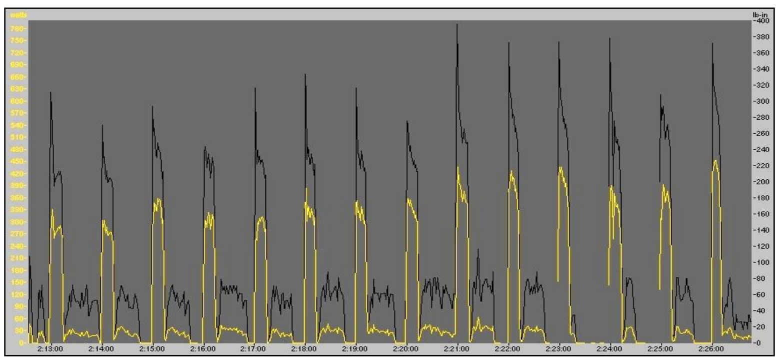
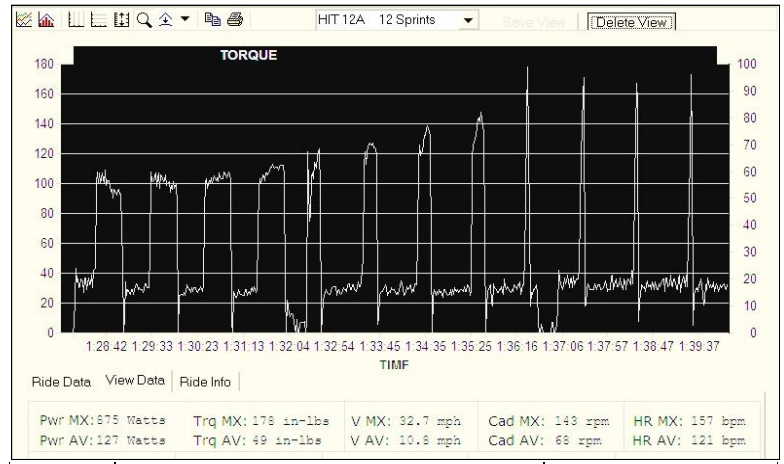


Figure 37. Torque training on stationary trainer. Crank torque, black; power, yellow. CyclingPeaks program display of SRM download of fourteen 15-second sprints.

Crank torque from about 300 to 400 pound-inches, or about 150 to 200 pound-inches per leg. Power from about 300 to 400 watts.

Such intervals will be at high-torque values, although maximum power development will be limited because lower cadences mean slower acceleration. Sprint training is best when it also includes moderate-gear high-torque maximum power and easy-gear high-cadence low-power training.

Be cautious about doing too much too soon—torque training is demanding on joints and ligaments as well as muscles. Learn and adapt to exercises before performing them "all out."



	Measured				Calculated	
Duration	**Peak Wheel Torque**	**Gear**	**Power**	**RPM**	**Crank Torque**	**@ Leg**
30-Sec	100	38/14	500	110	**270**	**135**
15-Sec	130	38/13	600	120	**380**	**190**
5-Sec	160	55/13	800	135	**680**	**340**

Figure 38 and Table 7. Torque training on stationary trainer. Four 30-second, 15-second, and 5-second intervals. Bigger gears and shorter intervals result in higher torque. PowerTap recording of wheel torque.

The critical crank torque and crank torque per leg is calculated. Power and rpm data, shown in the table but not shown in the figure because overlapping obscures torque values.

Isolated-Leg Training Doubles Torque

If wheel torque is 100 pound-inches, and crank torque is 400 pound-inches in a 52/13, consider the torque if riding with one leg:

Those 400 pound-inches of crank torque result from the average torque of both cranks, or legs. Each leg, on average, is producing 200 pound-inches of torque.

If you are performing isolated leg training (one-legged riding), all 400 pound-inches of the torque comes from one leg.

In the example shown below in Figure 39, one athlete performed his last set of isolated leg training at about 350 pound-inches of crank torque with each leg for 3 minutes.

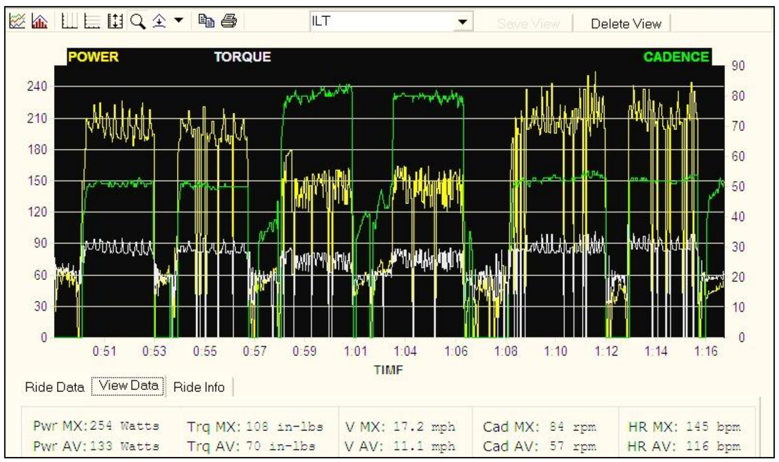


Figure 39. Isolated leg training, three sets. On the left, from the top: Power, yellow; cadence, green; and wheel torque, grey. The third set, on the right, 55/14 gear, power about 220 watts, cadence 53 rpm, wheel torque about 90 pound-inches.

Wheel torque of 90 pound-inches translates to about 350 pound-inches of crank torque per leg. This value can be calculated from (1) wheel torque X gear (90 X 55/14) or from (2) power / rpm X 85 (220/53 X 85).

Compare the 350 pound-inches of torque performed with each leg for 3 minutes during isolated leg training with the just 5 seconds of 350 pound-inches the athlete performed during each of 5-second intervals demonstrated in Figure 38, or with the 184 pound-inches the athlete averaged climbing a steep grade undergeared demonstrated in Figure 36.

Isolated leg training is excellent torque training.

Relative Torque of Typical Workouts

As discussed above, big-gear climbing, 15-second and 5-second intervals, and isolated leg training provide torque work. Isolated leg training typically provides the highest levels of sustainable torque training.

Workout	Crank Torque Watts per pedal stroke (pound-inches)	Crank Torque Per Leg Watts per pedal stroke (pound-inches)
10-minute interval	2.4 (200)	1.2 (100)
4-minute interval	2.6 (220)	1.3 (110)
Big-gear climbing	3.5 (300)	1.8 (150)
15-second sprint	4.7 (400)	2.4 (200)
5-second sprint	8.2 (700)	4.1 (350)
Isolated leg training	4.1 (350)	4.1 (350)

Table 8. Torque of typical workouts. Crank torque of a typical all-round 65-kilogram (143-pound) Cat 2 male racer. Isolated leg training generates the most sustainable torque work.

Torque-Training Guidelines

Torque-training workouts are identified in this book. The most common torque-training workouts outlined are isolated leg training and 5- and 15-second sprints.

Crank torque ranges are quantified, but vary greatly among riders. As with power ranges, these are scaled to weight. The higher ranges apply to fit, regional elite male athletes. The lower ranges generally apply to beginning male racers; fit, established young masters female racers; or elite older masters male riders.

Isolated leg training is typically performed at crank torques between 2 and 8 pound-inches per kilogram of body weight for each leg.

Five-second sprints are typically performed at crank torques between 5 and 13 pound-inches per kilogram of body weight for both legs.

Fifteen-second sprints are typically performed at crank torques between 3 and 8 pound-inches per kilogram of body weight for both legs.

As noted above, torque training is about crank torque: PowerTap measures wheel torque, and SRM does not display its crank torque measurements.

- Torque in pound-inches is power in watts divided by cadence multiplied by 85. Alternatively:
- PowerTap users: To convert wheel torque to crank torque, use the formula:
  Crank torque = wheel torque x (chainring teeth / cog teeth), or use the table on page 62.
- SRM users: Consider using a secondary program to view crank torque.

By noting PowerTap wheel torque or SRM power in a given gear, you can gain insight into your relative torque values from workout to workout.

Torque Summary

Riders and racers need to be able to produce power at low and high cadences—at high and moderate torque levels.

Train at lower and higher rpm to train your muscles and your heart.

In events, do not save your easy gears for later; save your legs.

Lower Cadence (<60 rpm)	Higher Cadence (80 to 100 rpm)
Higher torque	Lower torque
More fast-twitch muscle recruitment	More slow-twitch muscle recruitment
More fast-twitch glycogen use	More slow-twitch glycogen use
More muscle fatigue	Less muscle fatigue
More muscle soreness	Less muscle soreness
More microscopic muscle damage	Less microscopic muscle damage
Lower overall energy cost	Higher overall energy cost
Lower overall aerobic cost	Higher overall aerobic cost
Generally lower heart rate	Generally higher heart rate
Slower acceleration	Faster acceleration

Table 9. Physiological characteristics of lower and higher cadences for a given power output.

Practical Guidelines

Wheel Torque to Crank Torque

Crank torque provides a measure of muscle force.

The PowerTap measures wheel torque, not crank torque. To determine average crank torque multiply wheel torque by chainring teeth and divide by cog teeth.

Average crank torque per leg is one-half total crank torque, unless performing isolated-leg training (ILT, one-legged riding).

For example, wheel torque of 100 pound-inches equates to 408 pound-inches of average crank torque in a 53/13 gear, or 204 pound-inches of average crank torque per leg, unless performing ILT.

The table below provides a quick way to determine crank torque when wheel torque and gear are known. The conversion table columns note wheel torque for values 5 to 100 pound-inches, in 5 pound-inch increments.

Due to space constraints, wheel torque columns stop at 100 pound-inches. For wheel torque values between 100 and 200 pound-inches, find a value half the amount of wheel torque and double the value in the column. For wheel torque values between 200 and 300 pound-inches, find a value one-third the amount of wheel torque and triple the value in the column.

For example, for 160 pound-inches of wheel torque in a 39/15, double the value for 80 pound-inches, 208 to give 416 pound-inches.

Chainring	Cog	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
39	11	18	35	53	71	89	106	124	142	160	177	195	213	230	248	266	284	301	319	337	355
39	12	16	33	49	65	81	98	114	130	146	163	179	195	211	228	244	260	276	293	309	325
39	13	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
39	14	14	28	42	56	70	84	98	111	125	139	153	167	181	195	209	223	237	251	265	279
39	15	13	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	247	260
39	17	11	23	34	46	57	69	80	92	103	115	126	138	149	161	172	184	195	206	218	229
39	19	10	21	31	41	51	62	72	82	92	103	113	123	133	144	154	164	174	185	195	205
39	21	9	19	28	37	46	56	65	74	84	93	102	111	121	130	139	149	158	167	176	186
39	24	8	16	24	33	41	49	57	65	73	81	89	98	106	114	122	130	138	146	154	163
39	27	7	14	22	29	36	43	51	58	65	72	79	87	94	101	108	116	123	130	137	144
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
53	11	24	48	72	96	120	145	169	193	217	241	265	289	313	337	361	385	410	434	458	482
53	12	22	44	66	88	110	133	155	177	199	221	243	265	287	309	331	353	375	398	420	442
53	13	20	41	61	82	102	122	143	163	183	204	224	245	265	285	306	326	347	367	387	408
53	14	19	38	57	76	95	114	133	151	170	189	208	227	246	265	284	303	322	341	360	379
53	15	18	35	53	71	88	106	124	141	159	177	194	212	230	247	265	283	300	318	336	353
53	17	16	31	47	62	78	94	109	125	140	156	171	187	203	218	234	249	265	281	296	312
53	19	14	28	42	56	70	84	98	112	126	139	153	167	181	195	209	223	237	251	265	279
53	21	13	25	38	50	63	76	88	101	114	126	139	151	164	177	189	202	215	227	240	252
53	24	11	22	33	44	55	66	77	88	99	110	121	133	144	155	166	177	188	199	210	221
53	27	10	20	29	39	49	59	69	79	88	98	108	118	128	137	147	157	167	177	186	196

Table 10. Crank torque values for different gears, based on red wheel torque value of the top line of each chainring group.

Overtraining

"What drives you to succeed, drives you to screw up."
—Mari Holden, World Champion, Time Trial, 2000

Overtraining is a physical and a psychological or emotional state. It is an imbalance between training and recovery, exercise and exercise capacity. The "training effect" is the body's response to workload stress. If stress is too great, the body cannot respond and adapt. Overtraining may result.

What We're Talking About

Fatigue, apathy, lethargy, or staleness in otherwise healthy athletes.

Overtraining is a physical and psychological state. Most psychological states have a physical, biochemical, metabolic, and/or neurohormonal basis.

One of my rules of thumb is this: "When you look at the bike in the morning, are you raring to get on it or do you groan inside about the workout you have set for yourself?"

Overtraining symptoms include the following:

- Poor, non-restorative sleep
- Mood disturbances, including anxiety, irritability, loss of enjoyment, and sadness
- Poor performance with the same or increased training
- Vague or undefined physical complaints

A note about terminology: *Overloading* is a building or anabolic adaptation to workload stress. *Overtraining* is breakdown or catabolic response. *Overuse* is musculoskeletal overtraining.

Sometimes, the trick in maximizing human performance is to perform the greatest volume of intense training without overtraining. Some say: "Put your finger near the fire to know that it is hot, but do not burn it!" Push, yes, but not too hard all the time.

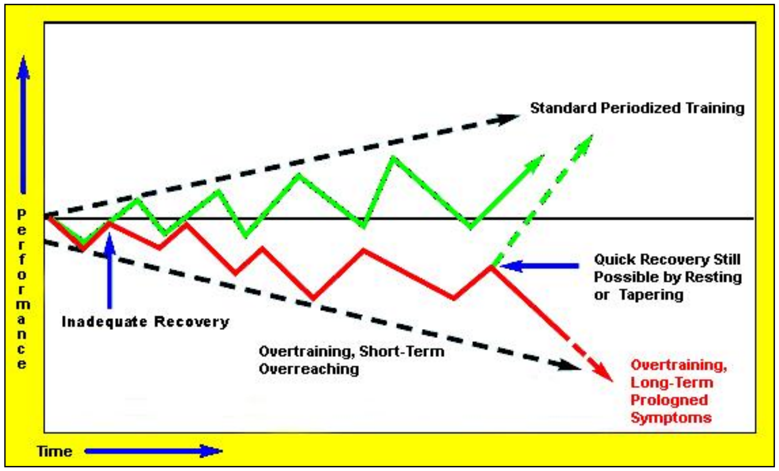


Figure 40. The road to overtraining.[27] The green line represents repeated cycles of training (overload) and recovery.

The red line represents repeats cycles of training and incomplete recovery (overreaching).

Bottom right: With prolonged overreaching, overtraining syndrome develops.

Keep in mind that a range in training volume and intensity may be optimal. The high end of the range may not be better, and a lot more may be worse.

If there is a range in training that will result in the same gains, it is often reasonable to perform the least, not the most, amount of work that will result in the same gains.

Consider this analogy: If your employer gives you $200 for working 6 to 10 hours, would you choose to work 6 hours, 10 hours, or 20 hours?

You need some easy days, some quiet friendly rides, maybe some bike touring. Ignore recovery training, and you may dig yourself a hole that not even a week or two off the bike can cure—then you may really lose fitness!

[27] Figure adapted from Hawley (2003). *Overtraining Syndrome*. The Physician and Sports Medicine, 31 (6).

Remember: It is not training that makes you fitter. It is recovery. Your fitness improves during the recovery from training.

If your weekly volume increases from 100 to 200 miles in a couple of weeks, you may be mentally eager to ride more, but your body may say no.

It is important to have a measured increase in workload to avoid fatigue. If you increase your mileage more than 10% per week, you should cut back on intensity, or you are likely to become tired.

You may be enthusiastic about getting stronger, and read a program on interval training. If you begin a serious program of interval training, even with a good base, it is difficult to maintain such a program without diversity and measurable results, or other positive feedback. If you do the same workouts day in day out, even though they may be physiologically sound, it is easy to suffer burnout.

Stress in Athletes

A combination of training and non-training stresses affect athletes.

Training stresses include:

- Too much volume
- Too much intensity
- Too little recovery

Common situations that result in training stress include:

- Excess competition.
- Attempts to follow training plan when injured or ill.
- Inappropriate increased training in an attempt to make up for rest related to injury or illness.
- Inappropriate increased training in an attempt to make up for poor competition performance.

Non-training stresses in athletes are similar to those in non-athletes and include:

- Excessive work, school, or family responsibilities
- Interpersonal conflict with co-workers, bosses, friends, or family
- Drug problems
- Housing problems
- Money problems
- Legal problems
- Illness or injury in self or others
- Insufficient sleep
- Travel—including jet lap and altitude changes
- Poor diet

Short- and Long-Term Overtraining

Short-term overtraining may be related to local muscle factors, including depletion of glycogen or muscle injury. Long-term overtraining involves, in addition, neurohormonal factors in the nervous system, including the brain and the endocrine glands.

Short-term overtraining, also called overreaching or isolated peripheral overtraining, is characterized by the following:

- Development over a few days to two weeks
- Exercise fatigue
- Reduction in submaximal performance capacity
- Reduction in maximum performance capacity
- Short-term inability (desire and physical capacity) to compete
- Recovery achieved within days
- Favorable prognosis

Long-term overtraining, also called overtraining syndrome, staleness, or combination peripheral and central overtraining, is characterized by the following:

- Development over a few weeks to months
- Exercise and non-exercise fatigue
- Reduction of submaximal performance capacity
- Reduction of maximum performance capacity

- Mood disturbance
- Muscle soreness/stiffness
- Long-term inability (desire and physical capacity) to compete
- Recovery requiring weeks to months
- Uncertain prognosis

How Is Overtraining Diagnosed?

Clinical symptoms, athletic performance, and medical tests point the way to the diagnosis. No test is foolproof or perfect. For most symptoms and tests, other medical conditions give similar profiles.

In self-monitoring, the best-known markers to watch for are these:

- Morning weight down more than 3%
- Hours of sleep down more than 10%
- Resting heart rate increased more than 10%
- Mood changes including fatigue, loss of enthusiasm and depression

Research suggests that with overtraining, relative to otherwise healthy adaptations, the following changes may occur:

- Maximum heart rate decreases
- Hormones change. Cortisol: resting and 8 A.M. blood levels of cortisol increase; post-exercise blood levels decrease. Catecholamines: levels decrease in urine at night by more than 50% and increase relatively more for the same intensity of exercise. Testosterone levels in blood decrease. Insulin responsiveness decreases.
- Blood chemistries change. Triglycerides, low-density lipoprotein lipids, and very-low-density lipoprotein lipids decrease. Maximum lactate and submaximum lactate decrease. Submaximum levels may (falsely) give the impression of improved performance. The ratio of blood lactate to perceived exertion decreases. Glutamine use decreases.
- Neurotransmitters change. Serotonin levels in the brain increase.
- Immunoglobins and the immune system change. Immunoglobulin A in saliva decreases.
- Muscle energy and water stores change in short-term overtraining syndrome. Glycogen is depleted, and intracellular stores of water are reduced.

Avoiding Overtraining

- Individualize training. One size does not fit all.
- Do not increase frequency, duration, or intensity too quickly.
- Allow for recovery. Plan and schedule rest days.
- Build up a good endurance base before undertaking interval work.
- Sleep at least eight hours a night.
- Consider afternoon naps, rest, or meditation.
- Review non-training stresses, and attempt to reduce or accommodate them.
- Avoid overcompensating for time missed from training.
- Avoid overcompensating for poor race performance.
- Adjust your goals.
- Eat a nutritionally sound high-carbohydrate diet to help prevent glycogen depletion.
- Hydrate.
- Monitor your morning pulse, weight loss, and sleep patterns for self-diagnosis of overtraining.

Medication: Depression and Overtraining

Medical depression and overtraining often share many of the same clinical symptoms. Functioning decreases in both. Medical or biochemical tests show similar changes.

Some believe that overtraining is one cause of medical depression. The converse is also true: Medical depression also lessens the ability to train.

Preliminary scientific investigation suggests that antidepressant medication may help athletes train harder, treat overtraining syndrome, and improve their performance.

Summary

- More is not necessarily better.
- Stress, both training and non-training stress, can be helpful and strengthen athletes, or if excessive can be harmful and weaken them.
- Increase training volume and intensity incrementally; allow for adaptation.
- Plan for recovery.
- Be alert to symptoms of short-term and long-term overtraining. Do not ignore them.
- Seek coaching or other advice if uncertain about your situation.

Recovery

Recovery is the readiness of fitness systems to make further efforts following training and non-training fatigue.

Training stressors relate to the volume and intensity of efforts.

Non-training stressors include psychological, climate, travel and many other factors.

Reducing training and non-training stressors reduces the amount of recovery required.

Improving recovery allows effective training to resume sooner or competition to be more successful.

Training and Non-Training Stress

Many athletes and coaches consider recovery only in terms of the physical exertion of training and racing.

Non-training factors, which will be discussed in detail, can significantly contribute to the stress load. By reducing or eliminating non-training stressors, athletes can train harder or compete more successfully.

Short-Term vs. Long-Term Recovery vs. Rehabilitation

Some types of fatigue result from a single training session. Other types of fatigue accumulate over multiple sessions or several weeks or months of training.

In the same way, some forms of recovery may be needed from a single training session; other forms of recovery may be required from a longer period such as a racing season. For example, nutritional recovery may be needed from a long endurance ride; psychological recovery may be needed from a racing season.

Short-term recovery and short-term overtraining, and long-term recovery and long-term overtraining form a continuum—they overlap.

Rehabilitation refers to an injured athlete. The need for rehabilitation may be the result of an accident or inadequate recovery—for example, from overtraining.

Markers of the Need for Recovery

How do you know if you need recovery?

Many athletes rely solely on how they feel. For example, their legs feel tired or heavy. Others feel relatively weak. Their mood may be tired or depressed; or they may lack enthusiasm.

Others use more objective methods. The first four bullets below are associated with a lack of nutritional recovery. Dehydration alone raises heart rate and decreases body weight. As carbohydrate energy stores (glycogen) in muscle bind roughly three times their weight in water, body weight may be down until glycogen is replaced.

None of the bullet guidelines below is foolproof—however, they can help athletes and coaches objectify the need for recovery:

- Resting heart rate elevated more than 10%.
- Orthostatic heart rate (the rise in heart rate that occurs when standing from a lying position) more than 20 beats per minute.
- Two-minute recovery heart rate after intervals raised more than 10%.
- Body weight decreased more than 3%.
- Sleep hours decreased more than 10%.
- Biochemical markers or lab tests. A variety has been used; few have proved valuable.

In general, if you think you need a day off, you are right, you do. If you know you need a day off, you need two.

Plan for Recovery

A common error is to train or race until too tired to continue effectively.

The essence of training is the equation: TRAINING = WORK + RECOVERY.

Improvements in fitness come from the recovery that occurs after training or racing.

Plan for recovery. Depending upon fitness level, after a hard day, plan to go easy the next. After a hard stage race, plan to ride easy for many days.

Specific Recovery from Training

Training stresses a number of physiologic systems. How to plan the recovery of training fatigue is outlined below:

Nutrition

Fluids

Sweat rates in hot, humid conditions are commonly about two quarts (liters) per hour. Higher rates have been recorded.

The best approach is to minimize losses during training or racing by drinking as tolerated up to a quart and a half during exercise.

Drink a bottle or two after your training or race—you are almost certainly dehydrated.

You may need to replace twice as much fluid as you have lost. If you are down three quarts after a long training session or race, it may take five or six quarts to replace your fluids.

This is because your kidneys will eliminate some of the fluid you drink before it has a chance to go to your tissues.

Sodium

Replacing the electrolyte sodium can help for many reasons.

1. Sodium stimulates thirst. Therefore, you are more likely to rehydrate.
2. Sodium helps the stomach and gut process fluids, and so improves fluid absorption.
3. Sodium helps the body hold on to water. If you are down three quarts and if you ingest sodium with your fluids you may need only four quarts to replace your fluids rather than five or six.
4. Sodium itself may need replacing. Many athletes lose about 1,000 mg of sodium per quart of sweat. If you have worked out for an hour or two and have lost only a couple of quarts your background daily intake of a few grams (say 3,000 mg) sodium is likely to be sufficient.

   If you have worked out long and hard on a hot, humid day, you may have lost 10 quarts of sweat. Now you must increase your sodium intake to replace your losses.
5. Sodium ingestion may help prevent cramps.

Energy Sources

If you are planning on training or racing again in the next few days, you have to resupply your energy tanks—and sooner is better.

If possible, it is best that you have consumed at least 300 calories per hour, mostly carbohydrates, while exercising.

How many calories you need after exercise depends upon how many you have burned and how many you have replaced along the way.

Assuming you have worked out hard for a few hours, and consumed 300 mostly carbohydrate calories per hour during exercise, you will need to replace 200 to 1000 calories of carbohydrate to restock your energy supplies.

Immediately after hard training or competition, liquid carbohydrates are often easier to consume than solid foods.

For many athletes, real foods such as sandwiches, fruit, yogurt, cookies, milk, and juices may be a better recovery choice than the more expensive and marketed recovery drinks.

Do not wait hours for dinner—certainly have dinner later, but eat something ASAP.

Protein

It is currently popular to believe that protein replacement after exercise is important.

Scientific evidence about the role of protein is unclear. Some advocate protein consumption equal to about one-fourth the amount of carbohydrate ingested. Some recommend the protein building blocks of glutamine and branched-chain amino acids.

Others doubt that more than about 6 grams of protein is needed, and believe that the protein has proven helpful only when protein has helped meet overall caloric need—when carbohydrate replacement has been insufficient.

Antioxidants and Other Vitamins

Exercise increases chemical reactions, often through a biochemical process called oxidation. This leads to so-called free radicals that *may* be associated with reduced immunity or cancer.

Antioxidants, including vitamin A and derivatives, vitamin C, and Vitamin E *may* reduce this oxidative damage.

The operative word is here is *may*. The scientific evidence that antioxidants or other vitamins aid recovery is hardly convincing.

Muscles

Get off your legs.

Those legs of yours have worked hard. Do not stand around for a couple of hours chatting or watching the next race. You can still be friendly and exchange war stories. However, sit down to do it—get off your legs.

Vibration

Mountain biking or rough road riding can result in vibration damage to muscles. Most athletes require cross-training on smooth roads to optimize the training of fitness systems and limit vibration stress to muscles.

Eccentric Damage

Work performed while muscles lengthen under tension often results in muscle soreness.

This type of exercise is not common during general bicycle riding; it does occur with some one-legged riding and high-cadence exercises. It is also typical of many weight-room routines.

Reduce or avoid this type of work for several weeks before racing.

Crotch/Buttocks

Pressure and moisture are hostile to skin health.

Biking shorts are great for biking—but the tightness and dampness are bad for crotch hygiene and promote saddle sores. Change out of those tight damp shorts promptly after rides.

Neoprene seat covers, double shorts, Bag-Balm, and post-ride warm baths are some of many methods of reducing crotch and buttocks stress.

Thermal Stress

Heat increases the metabolic demands on the body. If it is a hot sunny day, and you stay exposed, you will delay recovery. If you are not going home, get in the shade.

If it is cold or rainy, of course you will want to get out of the weather and get into warm, dry clothes as soon as possible.

Sunscreen

Of course, it protects your skin. It can also prevent you from becoming overheated and can keep you working longer. Preapply, carry, and reapply as necessary.

Eyes

Wind, dry air, sun, dust, pollution, bugs, and other debris tire the eyes.

Eye protection (e.g. sunglasses) helps reduce stress.

A cool, damp towel on the eyes after the ride and low-level lighting helps make the eyes feel better.

Training Routine

Varying workouts during the week, month and year (periodization) helps keep athletes physiologically and psychologically fresher.

Although hard work in training and racing may be required, many athletes benefit from training and racing “vacations.”

Allow yourself to adapt and progress before working at hard levels of perceived exertion.

Think of some of the things you do not want to do after hard training or racing. For example, you probably would not want to do heavy yard work. Do not fatigue yourself with such activities before heavy training or racing.

Warm Up and Cool Down

Gradually increasing the blood flow to muscles and allowing blood flow to carry away waste products after hard exertion are just two of many reasons why warm-ups and cool-downs probably reduce the need for, or assist, recovery.

Non-Training Stresses

Non-training stressors include psychological stress; travel stress including time-zone change; race-logistics stress; climate change stress; and ergolytics—performance-robbing foods, over-the-counter, recreational, and prescription drugs.

Psychological Stress

Although most athletes and coaches consider the psychological stresses of training and racing, many neglect the common, everyday life-stresses related to finances, relationships and family, and work.

Anxiety and depression prevalent in the general population is equally present in the athletic community. These everyday psychological stresses can significantly interfere with training and racing.

Of course, medical illness in self or family, death of a loved one, or the loss of a job are negative stresses. Psychological stress comes not only from “bad” things but can result from any change.

Too many good changes are also stressful and potentially an impediment to effective training and racing.

For example, a new job, relationship, marriage, a new car or house may be desirable. However, too many of these events close together can impede an athlete’s training or racing.

Resolving or limiting conflicts and major life events can help prevent or treat psychological stress.

Decrease Psychological Stress

- Keep things simple.
- Avoid sweating the small stuff.
  For example, a little change in diet is not worth more anxiety to “correct.”
- Keep perspective.
  Even if you have high cholesterol, if stranded on a desert island, it is okay to eat bacon and eggs (that is, if there are pigs and chickens around).
- Resolve problems.
  Do not keep dwelling on problems. Do not be stuck. Resolve conflicts and issues.
- Make sure goals are realistic.
  If you set unrealistically high goals, you will be stressed trying to reach impossible objectives.

- Plan; avoid crises.
  Take care ahead of time what you can. Plan to arrive early. Do not procrastinate; avoid rushing.
- Relaxation techniques.
  A variety helps many. These are discussed in more detail below. If you reduce life's stresses, you will not need to rush home to meditate.
- Strive for a psychologically healthy lifestyle: friendly, well-balanced, with good working relationships. Do not be contentious. Avoid contentious people.

Travel Stress

Although some athletes thrive on travel, most are stressed by it. Although professional athletes are helped by a road manager, checking into and out of hotels, sharing quarters, decreased or increased time alone, changes in diet including eating in restaurants, packing and unpacking equipment, rental cars, roads and traffic, missing items, and travel delays all contribute to travel stress and can burn out athletes.

Most athletes become familiar with their tolerance to travel stress. Athletes and coaches should schedule races to allow athletes to minimize travel stress before major competitions.

Decrease Travel Stress

- Prepared travel bags, toiletries.
  If you travel frequently, have dedicated clothes, toiletries, and travel gear permanently ready-to-go.
- Packing lists.
  If you race every weekend, you will probably bring more or less the same stuff. Have a checklist prepared so you do not forget anything.
- Extra time for delays.
  Give yourself a cushion. Allow for *Plan B*.
- Travel light.
  Do not weigh yourself down. Pack what you will likely need. Do not overpack.
- Luggage on wheels.
  Small or large, luggage you can roll saves lifting and carrying.
- Time zones.
  If practical, allow yourself one day per time zone crossed before major competitions. If you are traveling across more than five time zones, consider using a prescription sleeping pill for a day or two to reset your internal clock.
- Car rental #1 clubs.
  If you frequently rent a car, the convenience of a ready-to-go vehicle saves time and hassle on arrival and departure.
- Book motels ahead.
  Reservations are generally free. A downstairs motel room saves schlepping gear up and down stairs. Ask for a non-smoking room and a discount on the rack rate if you are interested.
- Known, tried fast foods.
  Travel a lot? Familiarize yourself with a few national chain restaurants, and find menu items that work for you. Avoid the unknown before major competitions.

Race Logistics Stress

Is preregistration required? How long before the race should I arrive? Where is the registration table at race site? Do I have my racing license? Did I remember my wallet? Is there a warm-up area? Where is it? Where are the toilets? Are there feed zones? Where? Is feeding allowed throughout the race? Is there neutral feed? Is there bike support? Are there pit areas? Is the race start hard to find? What is the start like? Is the start on time? The finish? Are the roads in good condition? Are there road hazards to be aware of?

Most of us are stressed to a greater or lesser extent by the details of racing.

Decrease Race Logistics Stress

- Packing lists.
  Who hasn't forgotten their shoes or racing license? Make a list. Check it twice.
- Maps.
  You think you know exactly where you are going, until you get off that freeway and do not remember the next turn.
- Preregister, prefill out entry forms.
  Preregistering generally saves some race-day long lines and hassle. If preregistering is not an option, fill out a standard athlete release, make copies, and use those copies to save time filling out race forms.
- Arrive early, but not too early.
  You need to have time to do all that you need to do. Allow a little extra. However, arriving hours early may increase psychological stress and expose you to adverse climate conditions, noise, and other noxious situations.
- Stationary trainer to warm-up.
  Mountain bikers should warm up their skills, too, on the dirt. If there is no warm-up area, or it is cold and rainy, a stationary trainer can allow you that super warm-up you want and need.
- Quiet.
  Stay away from noisy and busy areas of the venue that will interfere with your pre-race routine.
- Earplugs.
  Earplugs may improve concentration while warming up on stationary trainer or reduce noise stress while on the start line, especially for long mountain bike start-line introductions.
- Extra food and fluids in case of delays.
- Dry clothes for after the race.
- Do not hang around unnecessarily after race.
  Sure, you need to stay for the award ceremony if you have made the podium. You want to bond with teammates or fans. Nevertheless, as soon as you otherwise can, go back to the motel room or home, and avoid delaying recovery.

Climate Stress

Whether it is hot, sunny, and humid weather or cold and rainy, climate changes create stresses. The body requires adaptation to any new environment.

Decrease Climate Stress

- Heat and humidity.
  Acclimation takes about 10 days. If it is an important competition, and you have the time, acclimatize.
- Cold or wet.
  Get the right clothing and other gear to protect yourself from the elements.
- Altitude.
  If possible, allow one day at altitude for every 1,000 feet above your usual abode.

Ergolytics

Many ingested substances rob athletes of energy. These may be prescribed, recreational, or over-the-counter drugs. They may be herbs or foodstuffs.

Some of the substances touted to improve energy do help some athletes perform. Nevertheless, all substances have the potential to cause harm in some athletes.

For example, although caffeine helps some athletes, it makes others nervous, upsets gastrointestinal tracts, increases the need to urinate, reduces coordination, and worsens their performance.

Many substances usually worsen performance. For example, alcohol almost never helps and commonly hurts athletic performance.

Avoid new substances before important training or competition; use only familiar substances known to be helpful to you.

Rest

Rest helps training and non-training stresses.

Active Recovery

On recovery days, low-intensity training helps improve recovery for some athletes better than no training at all. The duration of this light training depends on the athlete. Riders who train 10 hours a week or less may find 20 to 30 minutes of light exercise helpful in promoting recovery. Some Tour de France riders may ride four hours on rest days to improve performance in later stages.

Riders often notice that they feel better after light training than at the beginning of their training session. Heart rates at the end of such sessions are often lower than at the beginning.

Light cross-training helps other riders. An easy swim, using non-cycling muscle groups, may be beneficial.

Passive Recovery

"Get off your legs," the creed of many cycling coaches, has merit.

Professional cyclists often avoid walking. They sit rather than stand; they lie down when possible.

When lying, they often raise their legs up, either on a recliner, or inclined up against a wall.

Mental Relaxation

There are many techniques. They include book and magazine reading, crossword puzzles, quiet music, and computer games. Specialized techniques include progressive autogenic and muscular relaxation, meditation, hypnosis, self-hypnosis, autosuggestion, autogenics, visualization, guided imagery, learning techniques, biofeedback, and electrodermal devices.

Sleep

Sleep provides the deepest rest of all. Many athletes perform best with nine or more hours of sleep a night. Many sleep researchers feel that not only athletes but also the general population is severely sleep deprived. Perhaps we would all do better with more sleep.

Napping helps many athletes. In general, avoid napping more than one and half hours daily or nighttime sleep quality may be reduced.

Good sleep hygiene improves sleep quality. Good sleep habits include:

- Regular sleep schedule.
  Generally go to bed and arise at the same time each day.
- Dark, quiet room.
  A blindfold or earplugs may help where noise or light is a problem.
- Avoid before sleep excitement, arguments, violent TV, alcohol, or other drugs.
  These often prevent a good night's sleep.
- Before sleep bath or read.
  A warm bath or good book helps many sleep soundly.
- Sleep on the right side.
  This helps many athletes. The heart's beating action is least noticeable when sleeping on the right side. This can be especially helpful if exercise has been late in the day and the heart's action is still forceful.

Ancillary Methods

There are many other techniques to improve recovery. Most methods should theoretically work by one or more of the following mechanisms:

- Increase blood flow to damaged muscles or other tissues
- Decrease muscle tension
- Accelerate inflow of nutrients
- Accelerate outflow or waste products
- Relax nervous system, reduce adrenalin

All of the methods described below have been found helpful by some athletes, although few have been shown scientifically to consistently work by any known physiologic mechanism.

Perhaps the underlying mechanism has more to do with the athlete's or coach's belief that the method works, or the psychological rest that the method allows.

Physical Therapies

Massage

Including self-massage, acupressure, shiatsu, trigger point massage, therapeutic touch, and reflexology.

Stretching

Including self-stretching, passive stretching, PNF (a form of assisted stretching).

Stretching should generally take place after, not before, training or competition.

Balneotherapy

Baths, saunas, and showers. Including hot tubs and whirlpools. Showers recommended at 99° to 105°, up to 10 minutes. Baths at 98° to 103°, up to 20 minutes.

Avoid overdoing it. Guard against increased fatigue or dehydration.

Other

Less common, but helpful to some athletes, including: light therapies, training in forests, floatation tanks, aromatherapy, postural realignment, Tai Chi, Yoga, magnets, ice therapy, vibromassage, exercise machines, electrostimulation, diathermy, laser therapies, acupuncture, barotherapy (with pressure chambers or gases), ultrasound.

Pharmacological

A number of drugs have helped some athletes. Some are prescription, some are over-the counter, and some are banned or illegal for use by athletes in or out of competition.

Since most do not help much or are banned, I list only a few examples:

- Anti-inflammatories, including aspirin, non-steroidal anti-inflammatory drugs, and COX-2 inhibitors.
- Herbs, including ginseng.
- Steroids and other hormones.

  Anabolic steroids in men and women; estrogens, especially in post-menopausal women; and human growth hormone probably do help recovery. Their use may be unethical or banned. They are often dangerous because athletes tend to misuse such substances with overdosage, combination with other drugs, or other hazardous practices.

A Personal Approach

If I travel to a ride or race by car, I bring a cooler and gallon jug of iced carbohydrate drink.

After the ride or race, I change into baggy shorts. I drink plenty of fluids and eat a variety of foods—often sandwiches, fruit, and cookies.

When I return home I have a warm bath, stretch my leg muscles in the bath. I then have an hour nap.

Summary

- Training and non-training fatigue requires recovery.
- Periodized training and planning for recovery helps keep the athlete physiologically and psychologically fit.
- Recovery from training includes fluids, calories, and rest.
- Reduce the need for recovery fluids and calories by drinking and eating during training or racing.
- The role of psychological factors in producing fatigue is important.
- Training and race-related stressors, including travel stressors, race-logistics stressors, and weather stressors can be reduced to improve physical performance.
- A variety of ancillary methods, including physical and other therapies, have proved useful to some athletes.

Measuring Training Stress

Introduction

Implicit in the very word itself, athletic training is the process of improving fitness.

Physical training is a stress, to which the body responds. As with all stresses, some stress may be good, too much may be bad.

How much is enough, how much is too much?

Can we qualify or quantify training stress in order to prepare and plan to obtain enough, but not too much; to improve, to provide adaptation, to peak, and yet not to overtrain?

A training log is basic to the process.

Training principles are discussed in detail beginning on page 21.

Bicycle workout variables include volume and intensity, as well as less common but potentially important factors including cadence, bicycle position, pedal stroke emphasis, and environment (altitude, climate, group setting, and terrain). These factors can help provide a qualitative or quantitative measure of training stress. For more information about bicycle workout variables, see page 25.

Quantitative training-stress measures generally relate to volume, intensity, or both.

As with measures of training volume and intensity themselves, all methods of evaluating training stress have pros and cons.

There is an interaction between training intensity and volume: as intensity goes up, volume must come down; and vice-versa: as volume goes up, intensity must come down.

Training stress indices have been developed that are based on both volume and intensity defined by heart rate or power.

Used singly or in combination, measures of training stress together can provide valuable insight.

Volume-Based Training Stress

Miles

Ask someone how much he or she rides.

Most US riders respond by quantifying their volume in terms of average miles ridden during a week (elsewhere, riders may quote their volume in kilometers).

Inexpensive bicycle computers make it easy to note and log miles ridden.

Other things being equal, the number of miles ridden provides one of the best and easiest methods of quantifying training stress.

A problem arises: other things are often not equal.

Hours

Riding Time

Some believe that mileage does not really count as much as time. The time-based approach is reasonable because in some ways the body responds more to riding time than to miles.

Consider: Alone, you might ride 15 miles in one hour. In a group, with drafting, you might ride 20 miles. It may be more accurate to express training stress in terms of one hour than 15 miles, or 20 miles.

Riding time may also be a simpler measure of measuring training volume for those who participate in more than one discipline, for example, road cycling and mountain biking.

Inexpensive bicycle computers may be set to start and stop at the end of rides, or to accumulate only riding time—for example, they may stop and automatically restart for traffic lights.

Chamois Time

Some feel that the moment you start riding until you finish a ride is all part of training and stress exposure, calling this time in the saddle, or chamois time.

This group feels that occasional stops during the course of a ride should not be discounted.

It is also easier, with just a watch and no bicycle computer, to note when you start a ride and when you finish, and calculate the total elapsed time.

If you arrive at your job at 9:00 AM and leave at 5:00 PM, have you worked an 8-hour day? Or have your worked 7 hours, because you took half an hour for lunch and had two 15-minute breaks?

Arguments can be made either way.

In looking at training stress for any given individual, and monitoring training time—whether riding or chamois time—what matters is consistency.

Climbing Volume

For those training for hilly centuries or ACE (Altitude-Climbing-Endurance) events, performance at the event and training stress is all about climbing.

Noting and logging climbing volume, with a simple computer that tracks positive elevation changes, may provide the best method of planning, recording, and predicting performance for climbing events.

Kilojoules of Work

Accurate power-meter computers, make it possible to document accurately the total work performed during a training session, week, or month.

Relatively expensive, such devices are becoming more common and a standard training tool for athletes and coaches.

Intensity-Based Training Stress

Perceived Exertion

Just ask: Was the ride hard, moderate, or easy? It is often easy to tell.

More complicated systems of rating perceived exertion include the Borg scale described on page 27.

Interval Work: Minutes

Some coaches and athletes monitor minutes of interval work per training session, week, month, or other period.

For example, coaches may prescribe 90 to 120 minutes of aerobic work at a heart rate over 80% of maximum per week; or a total of 5 minutes of sprint work a week.

An athlete who accumulates more than a certain number of minutes of training above a certain heart rate may be at risk for overtraining. For example, 180 minutes of aerobic work at 85% of maximum during one week may be an overtraining risk for some athletes.

Interval Repetitions, Number of Interval Sessions

The total number of intervals performed during a session, week, month, or other period may be used as a predictor of training stress.

The total number of training days with intervals per week or month may also be used as an indicator.

Many coaches believe that athletes should not engage in more than three interval training sessions per week; and that one or two such sessions may be enough, occasionally too much.

Interval Average Heart Rate, Power, or Work

The athlete's average heart rate, power, or work for intervals, for a climb, or for a race reflects how hard an athlete works.

Average heart rate may be an absolute number or a percentage of maximum.

Power may be average watts or average watts per kilogram. Interval work may be recorded in kilojoules. Like heart rate, watts values may be compared to the athlete's maximum capabilities.

Power-meter software may automatically find and report the highest average power for any segment from 5 seconds to 1 hour, or number of segments of any specified duration over any specified power level.

Number of Races/Racing Days

The total number of racing days per week, month, or season may also be used as a predictor of training stress.

Volume- and Intensity-Based Stress Indices

Volume and intensity may be combined to yield a single number or index reflecting training stress.

Heart-Rate-Based Indices: TRIMP and Variants

Eric Bannister proposed the Training IMPulse (TRIMP) in 1975. Others have developed it further.

The TRIMP score of a training session is determined by multiplying the training volume by the training intensity. There are many TRIMP-type methods and formulae.

Basic-Method TRIMP

- The simplest, basic-method formula is:

  TRIMP = training time (minutes) x average heart rate (bpm).

  For example, 30 minutes of exercise at an average heart rate of 150 beats per minute gives a TRIMP score of 4,500.

- A more sophisticated basic-method formula is:

  TRIMP = A x B x C

  A is training time in minutes

  B is (average training heart rate minus resting heart rate) divided by (maximal heart rate minus resting heart rate)

  C is 0.64 times $e^{1.92B}$, where e is 2.712.

These relatively simple formulae may be appropriate for athletes who exercise at a constant intensity—for example average exercisers in aerobic gym classes or recreational joggers.

These algorithms do not distinguish between different levels of training. For example, 30 minutes at 150 beats per minute gives the same basic-method TRIMP score as 25 minutes at 180 beat per minute.

Zone-Method TRIMP

Heart rate zones weigh intensity in the TRIMP calculation. TRIMP zone score is calculated as the cumulative total of time spent in each training zone.

For example, here is a five-zone system:

Heart Rate, % Maximum	Zone Weight
50% to 59%	1
60% to 69%	2
70% to 79%	3
80% to 89%	4
90% to 100%	5

Table 11. TRIMP zone-method system.

If maximum heart rate is 200 beats per minute, 30 minutes at 150 beats per minute gives a zone-score TRIMP of 30 x 3 = 90. Twenty-five minutes at 180 beats per minute gives a zone-score TRIMP of 25 x 5 = 125.

This zone-method TRIMP score distinguishes between training levels and remains mathematically relatively simple. Many downloadable heart rate monitors allow the user to set up such zones and will give minutes spent in each zone.

Precision-Method TRIMP

Computer algorithms can sample every downloaded heart rate value, give a different weight to every recorded value, and sum all.

This method is similar to the zone-method TRIMP above, but instead of five training zones, there may be over 100—say every heart rate from 80 beats per minute to 180 beats per minute.

Number of Intervals

Thierry Busso’s method calculates the training impulse by multiplying the number of intervals performed by their intensity based on heart rate.

His algorithm relates the positive gains from training and the negative gains from fatigue based on the real-world responses of athletes to his training impulse values.

Power-Based Indices

Normalized Power (NP)[28]

This index accounts for variability of power output during rides or ride segments longer than 30 seconds.

Normalized power is an estimate of the power that can be maintained for the same physiological "cost" if power output is constant rather than variable.

The algorithm attempts to integrate physiological response curves (principally glycogen use) to changes in exercise intensity.

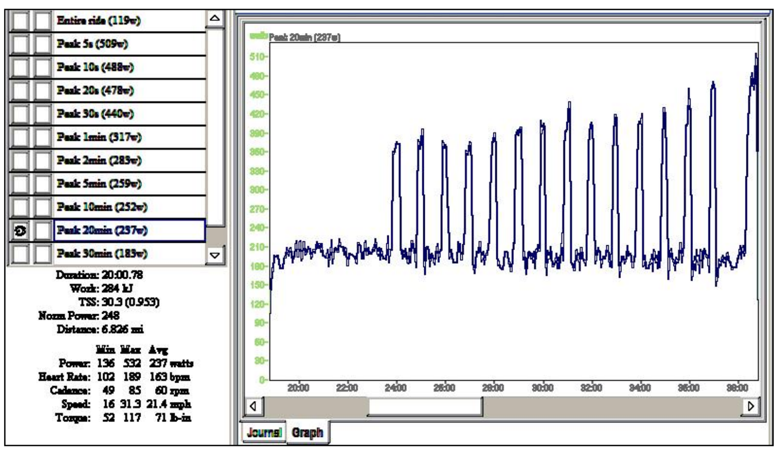


Figure 41. Normalized power. 20 minute stand with 15 surges from Standard HIT workout 8A. Power averages 237 watts. Normalized power is 248 watts.

For example, in Figure 41, the average power for a 20-minute effort with 15 surges was 237 watts. Normalized power predicts that this is physiologically equivalent to a steady effort of 248 watts.

Keeping track of normalized power purports to quantify more accurately the intensity of training sessions or races compared with average power.

Normalized power during a hard, one-hour criterium or road race may be similar to what a rider can average when pedaling continuously during a flat 40-kilometer time trial.

Normalized power from mass start races can provide an estimate of a rider's threshold power.

Intensity Factor (IF)

Normalized power does not take into account differences in fitness between individuals or for one person over time with changing fitness.

Intensity factor is the ratio of the normalized power, described above, to individual threshold power.

For example, if normalized power for a long training ride done early in the year is 210 watts and threshold power at the time is 280 watts, then the IF for the workout is 0.75.

However, if the same rider has the same power output later in the year, that is a normalized power of 210 watts, after fitness improves and threshold power rises to 300 watts, then the IF is lower, that is, 0.70.

Intensity factor provides a convenient way of comparing the relative intensity of a training session or race between riders, taking into account differences in threshold power.

For example, on a training ride one rider has a normalized power of 200 and a threshold power of 250 for an intensity factor of 200 / 250 = 0.8. A second rider has a normalized power of 170 and a threshold power of 200 for an intensity factor of 0.85. The ride was relatively harder for the second rider, even though normalized power was lower.

[28] *Normalized Power*, *Intensity Factor*, and *Training Stress Score*, were developed by Andy Coggan. Descriptions are adapted from the CyclingPeaks website, http://www.cyclingpeakssoftware.com/, accessed August 1, 2005.

Typical IF values, according to Coggan, for various training sessions or races are listed in Table 12.

Intensity factor can check for changes in threshold power without the need for formal testing. For example, an IF of more than 1.05 for a one-hour race is a sign that threshold power is greater than previously determined.

Intensity Factor	Typical Ride Description
< 0.75	Recovery rides
0.75 to 0.85	Endurance-paced training rides
0.85 to 0.95	Tempo rides, aerobic and anaerobic interval workouts (work and rest periods combined), longer (>2.5 h) road races
0.95 to 1.05	Threshold intervals (work period only), shorter (<2.5 h) road races, criteriums, circuit races, longer (e.g., 40 km) TTs
1.05 to 1.15	Shorter (e.g., 15 km) TTs, track points races
> 1.15	Prologue TTs, track pursuits, track miss-and-outs

Table 12. Intensity factors associated with typical rides or races.

Training Stress Score (TSS)

TSS is modeled after TRIMPS, described above. It takes into account both the intensity factor and the duration of each training session.

TSS, based on a one-hour time trial, is 100 points. A two-hour ride at a 0.7 intensity factor gives an equivalent training stress score of 100, and is metabolically equivalent, according to Coggan.

(I disagree. A one-hour time trial will fatigue me for two weeks. A two-hour easy ride may invigorate me.)

The following guidelines have been suggested by Coggan:

- < 150: Low (recovery complete by following day)
- 150-300: Medium (fatigue may be present the next day)
- 300-450: High (fatigue may be present after two days)
- > 450: Very high (fatigue lasting several days likely)

Power and Perceived Exertion Index

Stress-to-Strain Index

Allen Lim's stress-to-strain index is the ratio between actual work done calculated from direct measures of power and the work done calculated from perceived exertion.

"In the same way, we use a 'wind chill factor' or 'heat index' to correct for temperature, we use the 'stress-to-strain index' to correct for how hard (the rider) feels relative to … actual power."[29]

Index Value	Interpretation
<1.0	Rider feels effort was easier than what actually happened.
1.0	Perception of effort matches what actually happened.
>1.0	Rider feels effort was harder than what actually happened.

Table 13. The Stress-to-Strain Index

Confounding Variables

As discussed under measures of training intensity beginning on page 27, in heart-rate-based training on page 34, and elsewhere in this book, a host of factors can create discordance between measures of intensity (and therefore measures of training stress).

For example:

- Altitude
- Changing fitness
- Dehydration
- Glycogen depletion
- Group vs. solo riding
- Illness
- Medications and drugs
- Recovery/fatigue state from prior training

[29] Allen Lim, Bicycling Magazine online, http://www.bicycling.com/tourdefrance/experts/columns/0,5976,s1-12520-527,00.html?category_id=527, accessed August 4, 2005.

- Temperature and humidity
- Fast-twitch vs. slow-twitch muscle type
- Cross training, including eccentric training
- High-torque training
- High-cadence training

In some cases, confounding variables change the perception of effort. For example, riding in a group at 80% of maximum heart rate often feels easier than riding solo at 80% of maximum.

In other cases, confounding variables change the physiologic demands and stresses of the effort. For example, it is not just that riding at a given power output, say 250 watts, at an elevation of 8,000 *feels* harder than at sea-level, it *is* harder in terms of absolute power, heart rate, or speed that can be maintained.

Keep it Simple

Measures of training stress can be used to evaluate an individual training session, or multiple sessions over training cycles of weeks, months, or other periods.

Some coaches and riders may spend many hours poring over multiple variables and analyzing stimuli and responses. For many others, this is too much analyzing. Sometimes one single measure, despite limitations, works best.

If you use a power-based index to monitor training, keep in mind that every workout must be recorded with your power meter, or you will be missing data points.

As Tour de France team leader Floyd Landis has said: "I've seen guys pouring over data, analyzing and reanalyzing for hours. For me, I just want to know how much power I sustain on climbs and in time trialing."

Arnie's Simple Method

From coaching hundreds of athletes over many years, I have found that barely one half keep regular training logs—despite the fact that a log is basic to effective coaching, documenting training, predicting performance, and preventing overtraining.

Simplicity for the rider is therefore key, although as a coach, I am quite eager and willing to look at the minutia of heart-rate and power downloads, and provide detailed analysis.

At a minimum, I ask for just the basics—a single line per day on a spreadsheet, with a few figures and notes about the day's training.

After I am confident that riders know the meaning of easy riding, I like details from hard workouts including heart-rate and power files, and a grid of details for interval work.

For the basics, I use a simple Excel spreadsheet log with conditional formatting. This allows automatic color-coded highlighting of volume, intensity, perceived fatigue, mood, and a few other variables.

The color-coded conditional formatting is set to the level of the rider. For volume of training, in miles, a ride less than 20 miles might be color-coded green, a ride 20 to 50 miles color-coded yellow, and a ride more than 50 miles color-coded red.

I instruct riders to count as hard days those in which they race, perform interval work, or accumulate more than 30 minutes of work at heart rates greater than 80% of their maximums.

The colors create easy patterns to recognize. Lots of reds: beware of overtraining. Lots of greens: recovery period or perhaps not enough training stress.

A typical week's log is reproduced in Table 14. Note the Wednesday ride, discussed below, recorded on August 3rd.

Day	Date	Volume, Miles	Volume, Hours	Climb, K Feet	Work, Megajoules	Intensity	Intervals or Race?	PM / HRM?	SWL?	Group	Type	Location	Hours Sleep	Sleep Quality	Recovery	Resting HR	Mood in AM	Energy on Ride	Weight, Pounds
MO	**Aug 1**	0	0.0	0	0.00								8.0	5.0	5.0	47	5.0		
TU	**2**	40	3.0	0	1.0	H	I			ABC	Tandem	Fiesta Island	8.0	4.0	5.0	50	5.0	5.0	135.0
WE	**3**	65	6.0	5	1.8	M		PM		ABC	Road	Honey Springs	8.0	4.0	3.0	50	5.0	4.0	
TH	**4**	35	2.0	4	0.80	H	I	PM	Yes	ABC	Trainer	1820	8.0	4.0	4.0	48	5.0	4.0	
FR	**5**	5	0.5	0	0.2	E				Solo	Fixed Gear	Errands	8.0	5.0	3.0		5.0	4.0	
SA	**6**	50	4.0	3	1.5	H		PM		Club	Road	Gorman Loop	8.0	4.0	5.0		5.0	4.0	
SU	**7**	65	6.0	5	2.1	M		HRM		ABC	Tandem	DeHesa Japatul	8.0	4.0	3.0	50	5.0	5.0	

Table 14. Example of a basic training log, with color-coded conditional formatting. Columns record training volume in miles, hours, feet climbed, and kilojoules of work; training intensity in terms of perceived exertion, interval work, and racing; type of ride; and location. PM/HRM/SWL cross-references power meter, heart-rate-monitor, or specific workout logs for interval training. ABC is Arnie Baker Cycling coached group of riders. Columns for other markers of training and non-training stress, rated on a scale from 1 to 5, include: sleep quality, perception of recovery, mood, and ride energy. Other columns, not shown, calculate and chart weekly, monthly, and annual totals.

With experience, color pattern recognition makes it easy to notice too much or too little training, and to be on the alert for overtraining. The Wednesday ride on the 3rd was, for this athlete, a long ride performed at a moderate intensity. Overall, the week was a good week of mid race-season training, with two long rides, three hard days, one easy day, and one day completely off.

A Practical Example—Arnie's Wednesday Ride

For 20 years, I have ridden an endurance ride almost every Wednesday.

In its current version, we ride about 65 miles. The first and last hours are always at an easy pace as we ride through city streets to the outskirts of San Diego.

After some rollers, we climb 6.5-miles up Honey Springs Road, with almost 2,000 feet of vertical. Then a rest stop for refueling, a 5-mile race simulation culminating in a sprint, and up to 10 sprints points on the way home, mostly up rollers. Riders choose to participate or not in the race simulation and sprints.

For some us, the whole day is of low intensity; sometimes we work hard going up the climb or on the sprints, or on both.

How do our stress measures portray the ride?

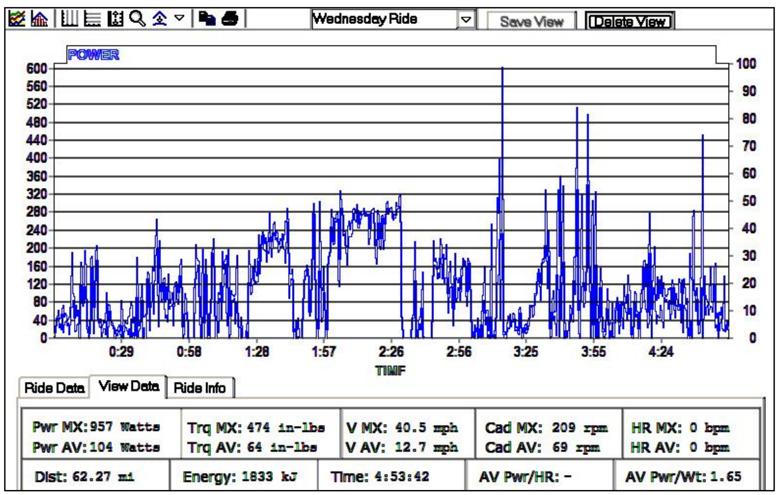


Figure 42. Typical Arnie's Wednesday ride. PowerTap download. Power, blue.
About 65 miles, 5 hours riding time.
Steady climb, about 30 minutes, at about 280 watts, at about 2 hours into the ride.
One sprint to 957 watts. Several other sprints to over 500 watts.

Volume

- *Distance*: The ride is always the same, 65 miles.
- *Time*: Chamois time is always about 6 hours, ride time about 5 hours. If we climb harder, we seem to need more recovery later and ride slower in the second half of the ride. If someone gets a flat tire, the rest period seems to energize us and we make up the lost time.
- *Climbing*: The ride is always the same, totaling about 5,000 feet.
- *Work*: The ride is always about the same, about 1,850 kilojoules for a typical 135-pound rider. Hard efforts are made up climbs and rollers; aerodynamics do not matter much. Whether one climbs Honey Springs in 30 minutes or one hour, the work against gravity is the same.

Intensity

- *Perceived exertion*: Can range from easy to hard, depending upon whether climbing hard, sprinting hard, or both.
- *Interval work minutes*:

  Intensity over 80% max heart rate: Riding easy, there may be only a few minutes; riding hard, up to 60 minutes.

  Sprint work: Zero to 5 minutes total.
- *Number of intervals*:

  Aerobic: Up to four 5- to 40-minute intervals.

  Anaerobic: Up to 10 sprints.
- *Interval average heart-rate power*: Our typical rider climbs Honey Springs at 135 beats per minute or 70% of maximum heart rate easy. He climbs at 165 beats per minute or 87% of maximum heart rate hard. Power ranges from 130 watts easy to 280 watts hard; or between 2.2 and 4.5 watts per kilogram.

Indices

To review the definitions of training stress indices, see the discussion beginning on page 78.

- *TRIMPS*: Our typical rider averages 300 minutes at 120 to 150 beats per minute for a 36,000 to 45,000 (simple, basic-method) TRIMP score.

- *Normalized power*: Our typical rider accumulates 1,850 kilojoules of work over 5 hours riding time and averages 370 kilojoules per hour, or about 105 watts per hour.

  Normalized power, accounting for variable power output, here mostly on climbs, ranges from a low of about 150 watts to a high of about 200 watts.
- *Intensity factor* is generally about 0.7. Riding easy results in a value of about 0.6. Climbing hard and performing all-sprints results in a value of about 0.8.

  According to the index's author, this generally represents a recovery ride.

  Note: If a rider performed the 0.8 ride, without our long warm-up and cool-down, the intensity factor would go up to 1.1, typical of a track points race or 15-kilometer time trial. The intensity factor would be higher for the shorter ride even though the longer ride would be everything the shorter ride was and more.
- *Training stress score* typically ranges from a low of about 200 to a high of about 300. According to the index author, fatigue may be present for one or two days after such TSS values.
- *Stress to strain:* Typically, the ride feels about as hard as the rider makes it. Confounding variables, such as heat during the summer, or riding following a hard Tuesday evening interval session, make it feel harder than it is.

Simple Method

It is a long-easy to long-hard ride.

Summary

Noting and recording one or more measures of training stress in a training log can help athletes and coaches monitor the adequacy or excellence of training or racing or both, and serve as markers for peaking or overtraining.

The bottom line for any individual: What works, what is easy to use, and what will be consistently used.

Stress Measure	Pros	Cons
Volume		
Distance	Simple, best with odometer Good if effort relatively constant	Misses intensity of segment
Time	Simple Good if effort relatively constant	Misses intensity of segments If distance is fixed, shorter times reflect harder, not easier workouts
Climbing	Simple, best with climbing computer	Misses intensity of segments
Kilojoules	Accurately reflects total work	Misses intensity of segments Requires power meter
Intensity		
Perceived exertion	Free Simple	Subject to confounding variables
Interval work minutes, numbers	Relatively simple for numbers and minutes	Requires power meter to quantify watts during intervals
Indices		
TRIMPS	Recognizes intensity of segments	Requires heart-rate monitor
NP	Recognizes intensity of segments	Requires power meter and software
IF	Recognizes intensity of segments Relates to individual	Requires power meter and software
TSS	Recognizes intensity of segments and overall volume of ride Relates to individual	Requires power meter and software
Stress-to-strain	Accounts for confounding variables	Complicated Requires power meter Requires prior testing
Simple		
Simple	Simple Conditional formatting makes pattern recognition easy	Less quantitative than some other methods Pattern recognition requires some science, some art, and some experience

Table 15. Pros and cons of different methods of evaluating training or racing stress. All measures are subject to confounding variables, as discussed on page 80.

Part 2: Interval Theory

Introduction

This section 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.

Intervals—periods of higher-intensity work interspersed with periods of lower-intensity work—are a common training technique. Interval training has been used by a variety of endurance athletes to improve performance for over 100 years.

Many cyclists benefit by changing their training.

Past training results in physiologic strengths and weakness. Training differently strengthens weak links.

Cyclists who have never specifically trained by performing intervals almost always improve with an interval program. Cyclists who performed one type of interval benefit by choosing another type. Cyclists who have a strong background in interval training may benefit from long, endurance rides.

Intervals are classified by the workload and rest periods, or by the physiologic fitness system thought to be stimulated.

For example, a popular interval prescription is a workout consisting of six 4-minute intervals, each separated by 3 minutes rest. Some might describe this workout as six VO_2 max[30] intervals.

Although coaches currently commonly classify the benefits of intervals by the physiologic fitness system stimulated, what counts in the real world are results: What works in practice and in fact.

To expand: Although 30-second intervals are physiologically classified as creatine phosphate/lactic acid tolerance training intervals, and theoretically might be expected to help performance only in short events, studies show that these efforts also improve 40K time trial times. Again, what really counts is what works.

Science has so far not been able to predict ahead of time which interval-training method works best. Thus far, coaching wisdom and experimentation has been more important than science. Sure, later sports scientists might say: “Of course! And here’s why.”

Coaches, athletes, and sport scientists disagree about interval variables. Duration of work interval, effort strategy, number of repetitions and sets, best cadence, recovery interval types and training frequency are only a few of the many variables.

The most popular training approach starts with base or endurance training, moves to longer, low-intensity intervals, and finally includes shorter, higher-intensity intervals. I agree with this approach. A minority of coaches advocates a year-round interval program, adding endurance training when needed.

Arguments In Favor of Interval Training

- Interval training allows a greater volume of high-quality work.
- Interval training allows for controlled high-quality work. Workload can be systematically and precisely prescribed, administered, and recorded.
- Controlled intervals with feedback (power output, distance, cadence, or other measures of workload) allow athletes to develop a sense of pace.
- Interval training allows aspects of fitness to be trained that otherwise would not be trained.

[30] VO_2 max is the maximum rate of oxygen consumption, often scaled to body weight.

Arguments Against Interval Training

- The individual response to interval training can be difficult to predict.
- Some cyclists find this type of exercise too complex or taxing.
- No scientific evidence exists that interval training is better than continuous training for mid-level aerobic work.
- Studies of interval training for high-level aerobic and anaerobic work are few and of marginal quality.
- Many professional riders do not consistently utilize interval training—yet some of these athletes possess high maximum aerobic capacities (VO_2 max >75 ml/kg/min).

  A rebuttal: Although some elite athletes do not engage in formal interval-training sessions, nearly all cycling races and training rides are conducted in an intermittent manner and therefore represent a type of interval training. The exceptional aerobic fitness levels achieved by some elite cyclists may be due to the interval format of their frequent racing. This allows these athletes to follow many interval-training principles without a formal program.

Three Interval-Training Basics

1. Spend some training time at or above event-specific intensity. Identify an interval-training session that will allow you to exercise at an intensity that is specific to the intensity at which you will compete (i.e., cycling speeds or power required during races).
2. Identify a duration of training at this intensity that will represent an overload (i.e., induce fatigue).
3. Determine how you will change your interval-training sessions as fitness improves over time, to progressively overload your body in a sport-specific manner.

Training Time at Race Intensity

Races represent the most specific type of physiological stress for cyclists. Unfortunately, races do not always progressively overload a cyclist in an optimal manner. Too much racing may promote overuse injuries and chronic fatigue.

How does one accumulate sufficient amounts of time at race intensities? A key is to recover appropriately so the body can adapt to intense efforts and to allow subsequent efforts to be of high quality. Interval training can simulate race-specific intensities, be prescribed at appropriate frequencies to allow for adequate recovery, and can be altered to progressively overload the cyclist in a manner that will result in improved performance.

Interval training can be used to promote overload with very specific control over the exercise intensity. For individuals competing in match sprints, 200m sprints, the kilometer, pursuit, or individual time trials, interval training can be used to increase time spent at competitive paces during training.

Training Program Principles

It is important to emphasize that intervals are only a supplement to a sound training program. Training programs also include resistance training, flexibility training, and continuous rides at a variety of intensities.

Interval intensity level may be (1) below, (2) at, or (3) above race-pace intensity.

1. Unless intervals are performed at a cadence, heart rate, power, or torque level above that of continuous work, interval work is unlikely to be of more benefit than continuous work.

   However, low- or moderate-intensity interval work may:
   - Help adaptation to high-intensity work
   - Build a bigger base/increase overall training volume
   - Increase general aerobic or muscular endurance
   - Assist in rehabilitation
   - Provide variety, reduce boredom
   - Provide workout structure, or
   - Improve neuromuscular technique or skill
2. Riders in some cycling events typically interval train at race-pace intensities. Track cyclists use race-pace specific interval training more frequently than road cyclists do. All cycling athletes can follow the same general guidelines discussed below.
3. Long-distance riders derive most of their training from continuous endurance riding. Intervals are performed above race-pace intensity.

Important variations of standard interval training may also be required to specifically train cyclists for real-world events.

For example, track cyclists may need stutter-sprint or double-sprint training (sprint to almost full power, pause, sprint to full power) to emulate the tactical demands of track sprinting.

Frequently, the best training is racing.

Conventional Wisdom

During endurance or base training, it is not necessary to regularly perform intervals at sport-specific intensity.

During the early pre-season, it may be beneficial to participate in one high-intensity interval-training session each week or every other week.

During the late pre-season, two to four interval-training sessions each week can provide increased discipline-specific overload to fine-tune the athlete for the demands of racing.

The majority of coaches advocate easier days before and after interval sessions to allow adequate rest and recovery, and the maintenance of interval quality.

In season, the road, criterium, and cross-country mountain bike racers can normally consider a race as an interval-training session and therefore one additional interval-training session at sport-specific intensity may be sufficient.

Races are of much shorter duration for the track cyclist. Two to four high-intensity interval sessions in addition to racing may be required so that fitness levels continue to improve.

Although the above is conventional wisdom, this is not proven. A number of respected cycling coaches have a different approach: Perform intervals year round, and add endurance training as the need for it develops during the racing season.

More High-Intensity Training

The fundamental argument in favor of interval training is: More high-intensity cycling time can be tolerated during interval cycling than during a maximum continuous effort.

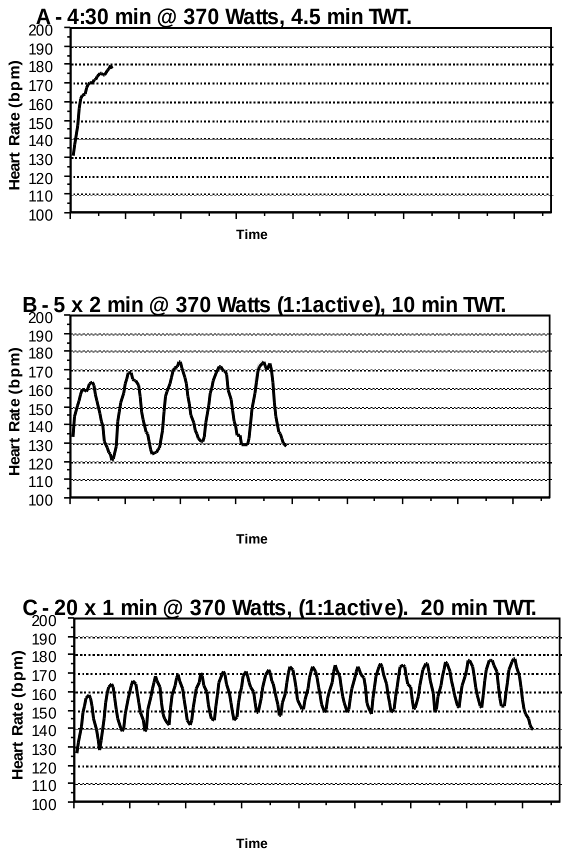


Figure 43. Interval training allows more high-intensity work. TWT = total work time.

Figure 43 shows three exercise trials[31] performed by the same athlete with several days' rest in between each trial.

The first trial is a continuous ride until exhaustion. The workload, previously shown to elicit 97-98% VO2 max, is 370 watts. The athlete performs 4 minutes 30 seconds of continuous work at this level.

The second trial is two-minute work intervals at the same workload. The athlete completes five such intervals for a total work time of 10 minutes.

The third trial, again at the same workload, shows that the athlete completes 20 one-minute intervals, for a total work time of 20 minutes.

[31] Graphs and data from Dean Golich and Dave Morris, United States Cycling Federation, 1995.

Cycling-Specific Intervals

Interval work is common in many sports; few sports other than bicycling have mechanical systems that allow for the manipulation of gear and cadence in prescribing interval work. Coaches often neglect these elements of the interval prescription. However, these elements are crucial to training the desired physiology.

For example, 3 minutes of big-gear work in a 53/12 gear at 50 rpm and at a heart rate of 170 is different from 3 minutes of small-gear work in a 39/26 gear at 150 rpm and at the same heart rate, 170. Although the heart rate and duration are the same, and both result in aerobic stimulation, the first interval tends to emphasize muscle strength and the second neuromuscular fitness.

Classification of Intervals

By What You Do

Intervals can be described by the following elements:

- Length of the interval
- Intensity of the interval
- Gear
- Cadence
- Length of the recovery period
- Number of intervals
- Number of reps and sets of intervals
- Training frequency

By Physiological Fitness System

Intervals can be classified based on what fitness system the interval is thought to train. For example:

- Lactic acid tolerance
- Lactic acid and lactate clearance and metabolism
- Maximum aerobic capacity
- Neuromuscular
- Muscular

Although this classification method is currently popular, it remains somewhat theoretical.

Interval Term	Definition
Interval training	Bouts of exercise alternated with relief.
Work interval	Period of work, normally a relatively short, hard effort.
Continuous	Non-interval training. Training without work and recovery periods.
Intensity	Load or speed of the work or resistance to be overcome.
Density	Volume of intensity during a time period.
Relief, recovery interval	Period between work efforts.
Work : relief ratio	Ratio of high-intensity to relief time. A 2:1 ratio means work interval is twice as long as relief interval.
Repetitions	Number of efforts within a set or training session.
Set	Group of repetitions.
Duration	Length of a specified work/interval.
Volume, total work time	The total time of intense work. In continuous training volume and duration are the same.
Training frequency	The number of interval workouts per week or month.
Training prescription	A shortcut format for describing interval work. For example, 2 sets, 3x4' @ 300 watts, 1:1, 1:2 (active) means: Two sets of three four-minute intervals performed at 300 watts, with four minutes recovery between repetitions, eight minutes recovery between sets.

Table 16. Interval terms.

Effort Strategies

Effort strategies within and between intervals are summarized in Table 17.

Although athletes and coaches imply otherwise, within each interval it is simply not possible to perform an interval longer than about 10 seconds "all-out." Longer intervals are paced—whether consciously or subconsciously—or power output must fall during the interval.

For efforts longer than 10 seconds, the strategy might be to (1) pace effort evenly; or (2) increase effort as the interval progresses (crescendo); or (3) start out with greater effort than is possible to maintain, and fade (decrescendo).

Another effort strategy within intervals is (4) intermittent surges. This is the least common effort strategy. However, inconstant effort characterizes all cycling events, and has a place in interval training. Even track sprinters, whose efforts over 200 meters may last barely 10 seconds, need to modulate their efforts in competition.

Within Each Interval Repetition	Subsequent Intervals in Set
1. Constant power	1. Same average power
2. Increase power to end	2. Each interval a little harder
3. Start out hard and fade	3. Start out hard and fade
4. Intermittent surges	
5. Set pace, below maximum possible	

Table 17. Effort strategies.

Finally, (5) a pace-based effort strategy, generally at power outputs lower than the first four options, is commonly used by track and road time trialists.

Each of these approaches has merits in specific circumstances. For example, a one-kilometer track effort done "all-out" will likely not result in the best time, but may result in the highest levels of blood lactate.

For almost all intervals, heart rate will rise during the interval. The initial rate of acceleration will be the highest for decrescendo (start out hard and fade) intervals.

For most intervals, a negative split, or crescendo approach to effort, works best.

Effort strategy applies not only within each interval but also for subsequent intervals in the set. If six intervals are to be performed, the strategy might be to (1) perform all of them with the same average power output, (2) perform each one at a slightly higher average power output, or (3) perform the first one as hard as possible and, inevitably, fade.

Again, strategy (2) generally works best. For most riders this approach results in the most work with the least psychological effort. For a recorded and downloaded example of this approach, see Figure 101 on page 179.

Specificity and Overload

Interval training can closely mimic or exceed the demands of a variety of different cycling events, in accordance with the training principles of specificity and overload.

Specificity

A specific cycling fitness may not occur frequently in a given race but may be crucial for success. Whether it is high cadence, aerobic capacity, power, or torque, these elements of fitness can be specifically addressed through interval training.

For example, after a long criterium or road race, a sprint finish frequently determines the winner, although this part of a particular event may comprise less than 1% of race time. To be prepared for this physical demand, considerable training and exposure to this fitness demand may be needed.

Interval training, intermittent by nature, represents a form of training that can mimic the demands of most cycling events.

A criterium or road race may last from 20 minutes to many hours. The intensity of the effort is not continuously high for the duration of the event. Intensity rises and falls intermittently depending upon terrain, environmental conditions, and race tactics. Even in team-time trial events, cycling intensity varies between high and moderately-high levels due to drafting.

Overload

Cyclists commonly participate in long, continuous rides in hopes of enhancing fitness. Long rides are necessary to enhance aerobic fitness and endurance. Endurance overload is achieved in many cases by riding longer and longer distances.

For other aspects of fitness, shorter, intense efforts are also required.

Short, high-intensity efforts can be incorporated into the long-distance training session, but when these efforts are performed on a fartlek or sporadic basis, it is difficult to record accurately the magnitude of the training overload.

Time spent at a specific intensity can be more easily determined during interval training. This type of training is desirable for those interested in prescribing and recording workouts that progressively overload the cyclist.

Exercise Oxygen Content

At altitude, there is less oxygen. (The percentage of oxygen in the air is the same as at sea level; the amount of air is less.)

Less oxygen means that less oxygen-dependent or aerobic work is possible. More oxygen means that more aerobic work is possible.

Similar to the concept that training at the same power output in a bigger gear emphasizes muscular fitness and a smaller gear emphasizes aerobic fitness, changes in the amount of oxygen may selectively emphasize or help train different aspects of fitness. (For example, emphasizing anaerobic or aerobic muscle-fiber development. This is conjecture, not proven.)

As noted throughout this book, a variety of interval lengths and intensities are helpful in improving cycling fitness.

Similarly, studies have suggested that some interval work with reduced oxygen and some interval work with increased oxygen may improve cycling fitness.

Sea-level athletes can reduce oxygen by traveling to higher elevations. Athletes living at higher altitude can travel to lower elevations with more oxygen.

In addition, it is possible to artificially reduce or increase inspired oxygen while training on stationary trainers through devices and other equipment, including reduced- or enriched-oxygen air masks.

Progression

Do not start interval training working "all-out" or "as hard as you can." Such an approach is psychologically and physically damaging. It risks overtraining and overuse injuries.

Follow the following progression:

1. Orient
2. Adapt
3. Build
4. Maximize
5. Back off/recover
6. Peak
7. Translate to event.

1. Orient

Before starting hard work, learn proper form or technique. Perform efforts at less than 75% intensity to orient yourself to the task.

2. Adapt

Allow your body time to adapt to the exercise. In some ways, you may already be able to work at higher intensities, in other ways you may not be.

For example, you may be physically able to perform high-rpm intervals, but until you adapt, excessive soreness after high-rpm intervals is likely.

3. Build

Work harder and progress in intensity.

4. Maximize

Work as hard as possible or "all-out" to perform as much high-quality interval work as possible.

5. Back Off / Recover

Although you may continue to perform the same type of interval work in a subsequent session or two, reduce the intensity of intervals.

6. Peak

Again, work as hard as possible or "all-out." Workloads may now be higher than the previous maximum work.

7. Translate to Event

Interval work is often best performed on a stationary trainer, where efforts can be precisely controlled and tuned. However, after peaking on a trainer, translate these workouts back to the terrain of your event—whether dirt, road, or velodrome.

Training as Fitness Increases

As you adapt to training, you will need increasing demands to keep making progress. Options include:

1. Increase interval workload; keep recovery periods the same.
2. Shorten recovery periods; keep interval workout the same.
3. Increase the number of intervals; keep workload and recovery periods the same.
4. Increase the workload during the recovery period.
5. Increase the number of workouts per week.
6. Increase fatigue state—the workload before intervals.
7. Plan for recovery: Train for a block of time; then give interval training a rest.

What Kind of Intervals Should I Do?

Intervals for Different Events

Specific interval prescriptions for different cycling disciplines are presented below. These are examples of one approach. Many other interval-training methods might also make sense, or prove helpful.

A. Intervals Based on What You Do

200 Meter Sprint

In a 200-meter (m) sprint, the goal is to accelerate and obtain a very high absolute speed for 10 to 15 seconds (up to about 45 mph for a world-class man).

To replicate the intensities utilized during competition, very short efforts lasting only 5 to 15 seconds need to be performed. The cyclist performs each repetition of interval training at maximum "all-out" intensities. Relief intervals need to be long in duration to allow for nearly complete recovery. Inadequate recovery results in sub-maximum efforts.

The number of repetitions is dependent upon how many high-intensity efforts can be generated. After the quality of the intense efforts decreases, the athlete is faced with the option of increasing recovery periods or stopping the interval session. Speed or power output can be monitored to gauge quality. Heart rate is unreliable for short intervals.

As with all high-intensity interval sessions, the 200m sprinter should plan to perform intervals when well recovered from previous bicycle or lifting sessions.

A desired progression involves increasing the absolute intensity (speed) of work efforts; not necessarily increasing the number of repetitions performed. As the cyclist adapts to the interval training, he/she can then complete each interval at a higher absolute speed (this continues to represent 100% effort).

A sport-specific muscle overload may be introduced by slightly increasing the weight of the bicycle and/or the rider or by using heavier gearing. Lighter gearing will help aerobic and neuromuscular training. These techniques may be helpful for those athletes who have reached a plateau. It is important not to significantly alter technique.

Initially a 100% effort is below the desired race intensity. As the cyclist adapts, maximum efforts result in faster and faster speeds.

Kilometer

The intensity of effort during a 1-kilometer event is very high. World-class men ride about 39.0 mph. Athletes achieve about 88% of the average velocity obtained in the 200m sprint.

Many kilometer racers can accelerate to and maintain world record kilo pace for approximately 0.2 kilometer. Only one individual (the world record holder) can maintain that pace for an entire kilometer.

A kilo rider can usually perform initially 0.3-kilometer intervals at target competition pace. During the first week of interval training, perform three repetitions with 30 to 60 seconds of active recovery.

As the cyclist adapts and becomes able to complete three to six sets of these intervals (each set represents 1 kilometer), progressively decrease the recovery period; hold constant the desired pace.

Eventually the kilo rider rides at the desired competitive pace and completes three repetitions of 0.3 kilometer with only 10 to 15 seconds of recovery between repetitions.

Only the rest periods are decreased. The number of intervals and the speed of the intervals remain the same.

Pursuit

A pursuit rider races at a submaximum velocity. The average velocity for the pursuit is about 75% of the average velocity obtained during the 200m sprint.

Many pursuit specialists at the regional level can maintain a world record pursuit pace (about 33 mph) for up to a kilometer.

The pursuiter identifies the racing speed needed to accomplish a desired time. The speed selected will initially be impossible to sustain for 4 kilometer; it can be maintained for 1 kilometer.

Perform two to three sets of 4 x 1-kilometer intervals at the desired pace with 30 to 90 seconds active recovery for the first couple of weeks.

As fitness improves, gradually decrease the recovery periods down to 5 to 15 seconds.

Progress to complete two 2-kilometer intervals or one 3-kilometer interval and one 1-kilometer interval with a 10 to 20 second relief period.

Criteriums and Road Races

To be successful in both criteriums and road races it is generally not enough to possess an exceptional aerobic capacity. The athlete also needs anaerobic fitness to deliver repeatedly near maximum efforts of varying duration. The ability to sprint effectively after a long and arduous ride often separates a winner from the rest of the pack.

Performing shorter intervals while “fresh” develops sprinting capabilities and a variety of training techniques improves aerobic fitness. However, neither of these training methods insures improved sprinting capabilities at the end of a race.

Train the capability to sprint at the end of a race specifically by performing intervals at the end of a continuous ride. End-of-the-ride-intervals may include 5 to 10 repetitions of 10 to 20 second maximum efforts with 1-2 minutes of active recovery.

It is important that these intervals represent a maximum effort if they are to be effective.

After beginning to adapt to this type of training, the cyclist should perform longer and more intense continuous rides prior to the intervals. This will pre-fatigue muscles in a way that is similar to the fatigue that occurs during a race. In this fatigued state, the athlete attempts to perform maximum intensity sprints. Not only will the body be subjected to a sport-specific training stress, but the competitor will also become mentally accustomed to the demands of vigorous efforts at the end of long hard rides.

The speed of the sprint efforts will allow the rider to determine what duration and intensity of continuous rides affect the quality of the sprint.

For criterium specialists, continuous rides may include a series of shorter intensity surges (20 to 60 seconds).

Road racing specialists may want to perform more sustained intensity surges (5 to 10 minute) to replicate intensity fluctuations that normally occur during a race.

Cross Country Mountain Biking

Professional cross-country mountain bike events last more than two hours. They are characterized by a considerable amount of time spent around threshold power outputs.

Many erroneously consider cross-country mountain biking to be similar to a road time trial. Whereas road time trials are characterized by power outputs within a relatively narrow range, cross-country mountain biking requires more intermittent efforts because of not only terrain changes but also tactical considerations. To gain position, the start typically requires up to four times as much power as the power average for the event’s duration. Gaining positional advantage before single-track, downhill, or other sections may also require large anaerobic efforts.

Interval training with recovery periods of relatively high intensity may specifically recreate some of the demands of mountain bike racing. Increasing the interval or recovery intensity are both possible approaches to training as fitness develops.

Downhill Mountain Biking

Many near maximum anaerobic efforts combined with only partial recovery characterize downhill mountain biking.

Increasing intensity with complete recovery, keeping intensity constant while decreasing recovery, and high-intensity intervals with some intensity during recovery are all reasonable approaches to cycling discipline-specific interval training.

B. Intervals Based on Physiologic Fitness Systems

Physiologic demands on the body depend on the duration of the effort. For a given duration of effort, certain physiological fitness systems are thought to limit performance. Classification of cycling intervals may be based on the most important physiologic fitness system believed to be performance limiting.

Table 18 lists common physiologic fitness systems and their abbreviations. Table 19 lists the common types of cycling intervals based on fitness systems.

Abbreviation	Fitness System
CP	Creatine phosphate
LATT	Lactic acid tolerance training
LC	Lactate clearance
Muscle–FT	Muscle, fast twitch
Muscle–ST	Muscle, slow twitch
NM	Neuromuscular
VO_2	(Maximum) oxygen consumption

Table 18. Fitness systems.

It is reasonable to think that the fitness systems required for relatively steady-state time trial events—whether relatively short, timed track events or individual efforts lasting more than one hour—include a variety of physiologic limiting systems both above and below the most-important limiting system for the event.

200m Sprint

The physiologic elements involved are the anaerobic creatine phosphate (CP), fast-twitch muscle, neuromuscular, and lactic acid tolerance systems.

Theoretically, a variety of the first three interval types summarized in Table 19 will assure the proper training of the systems needed.

Kilometer

The systems above and below this roughly 60-second event include anaerobic CP, lactic acid tolerance, and VO_2 systems.

Theoretically, a variety of the 3rd through 10th interval types summarized in Table 19 will assure the proper training of the systems needed. Neuromuscular training (10th interval type) will be for the lower duration range (2 minutes rather than 10 minutes).

Pursuit

The physiologic systems above and below a roughly 3 to 5 minute event (event distance 2 to 4 kilometers dependent upon rider age) are lactic acid tolerance, maximum aerobic capacity, and lactic acid clearance.

Theoretically, a variety of the 3rd through 10th interval types summarized in Table 19 will assure the proper training of the systems needed.

Criteriums, Road Races, and Cross-Country Mountain Biking

The physiologic systems involved include all the intervals types listed in Table 19. A variety of these, perhaps periodized, will help assure proper training of the systems needed.

Downhill Mountain Biking

The physiologic systems involved include the first 11 interval types listed in Table 19. Theoretically, a variety of these, perhaps periodized, will help assure proper training of the systems needed.

Fitness System	Common Names	Duration	Effort Intensity %		Gear	RPM	HR @ End Interval		Lactate	Recovery Length	Work: Recovery	Intervals /Session	Sessions /Week
			Start	**End**			**If Max = 200**	**% Max**					
CP, Muscle–FT	Power Start	4–15 sec	100	100	Hard	10–75	Unreliable	Unreliable		1–5 min	1:4–1:25	20–30	2–3
CP, NM	Sprint, Short	4–20 sec	100	100	Mod	135–170	Unreliable	Unreliable		1–5 min	1:3–1:25	20–30	2–3
CP, LATT	Sprint, Long	30 sec	98^+	100	Mod	120–170	Unreliable	Unreliable	12–18	1–15 min	1:2–1:30	8–15	2–3
LATT	Kilo	60 sec	95^+	98^+	Mod	110–150	185^+	92^+	12–20	2–5 min	1:2–1:5	5–15	2–3
LATT		90 sec	92^+	95	Mod	110–140	190^+	95^+	10–18	3–10 min	1:2–1:6	5–12	2–3
LATT, VO_2		2 min	90^+	85–95	Mod	110^+	185^+	92^+	8–16	4–15 min	1:2–1:7	4–10	2–3
VO_2, LATT	Decrescendo	3–5 min	85–95	75–85	Mod	80–120	180^+	90^+	6–14	3–5 min	1:1	4–8	2–3
VO_2	Anaerobic/Speed-endurance	3–5 min	85–90	85–90	Mod	80–120	180^+	90^+	6–14	3–5 min	1:1	4–8	2–3
VO_2	Crescendo	3–5 min	80–90	85–95	Mod	80–120	180^+	90^+	6–14	3–5 min	1:1	4–8	2–3
Neuromuscular	High-Cadence	2–10 min	75–85	75–95	Easy	110–150	150^+	75^+	4–8	2–5 min		1–10	2–4
LC	Max Steady State Threshold	8–20 min	75–85	85–92	Mod	75–100	175^+	88^+	5–10	4–10 min		2–6	2–3
Aerobic	Tempo, endurance	10–60 min	75–85	75–85	Mod	75–100	150–170	75–85	4–6	2–10 min		3–15	2–5
Muscle–ST	Strength-Endurance	3–20 min	70–75	75–80	Hard	50	150	75	4–6	1–10 min		2–6	2–4

Table 19. Common types of cycling intervals based on fitness system.

C. Intervals Based on What Works

Although coaches or athletes may believe that certain approaches work, perhaps in a perfect world scientific studies would clearly show what training approaches work.

Although the conventional wisdom is that properly-selected interval training helps all cycling disciplines, there are simply few or no scientific studies that demonstrate that specific interval approaches are effective or are more effective than others are.

Studies have not systematically examined even a small fraction of the permutations of interval types (length, intensity, repetitions, recovery length, sessions per week, number of weeks).

As previously noted, unless intervals are performed at a cadence, heart rate, power, or torque level above that of continuous work, interval work is unlikely to be of more benefit than continuous work.

There are about a dozen cycling-specific studies of interval training in the scientific literature.

About a dozen additional studies in the literature describe outcomes in runners and skiers. The results of these studies may not be applicable to cyclists.[32]

Almost all cycling-specific studies are otherwise of marginal quality.

- Studies may lack a control group.
- Sample sizes are small, rarely as many as 10 subjects.
- Blinding of subjects or examiners is rare.
- Studies may not be of moderately- or highly-trained cyclists.
- Almost all studies take place out of the competitive season, when many established athletes are detrained.
- Most studies use 40-kilometer time-trial performance, ramped power, or VO_2 max as endpoints. Few studies have looked at the ability to perform repeated surges during high-end aerobic work—an ability that determines success in many cycling events.

Thus far, studies have pointed to intervals of about 4 minutes and 30 seconds duration as being effective. Intervals of 1 minute, 2 minutes, and 8 minutes, have not been as helpful.

However, to repeat, there are so few studies that it is hard to draw any firm conclusions from them.

Listed and tabulated below are the cycling-specific studies of interval training I have found, in chronological order published. All studies are of moderately- or highly-trained cyclists, with the exception of the Tabata study of varsity athletes, the 2005 and 2006 Burgomaster studies of recreationally-active athletes and her 2008 study of non-actively exercising subjects.

Other cycling-specific studies of non-athlete, non-cyclists, such as those of MacDougall[33] Parra[34], and Rodas[35] are not discussed.

Tabata's[36] study of male physical education students, most non-cyclist varsity athletes, is included to illustrate potential problems with studies of small groups, non-cyclists, and the need for a control group: Both groups significantly improved fitness.

[32] For a review of such studies, see Paton, CD, Hopkins, WG (2004.) Effects of High-intensity Training on Performance and Physiology of Endurance Athletes. Sportscience 8, 25-40.

[33] MacDougall JM, Hicks AL, et al (1998). *Muscle performance and enzymatic adaptations to sprint interval training.* Journal of Applied Physiology, 84, 2138-2142.

[34] Parra J, Cadefau JA, et al (2000). *The distribution of rest periods affects performance and adaptations of energy metabolism induced by high-intensity training in human muscle.* Acta Physiologica Scandinavica, 169, 157-165.

[35] Rodas G, Ventura JL, et al (2000). *A short training programme for the rapid improvement of both aerobic and anaerobic metabolism.* European Journal of Applied Physiology, 82, 480-486.

[36] Tabata I, Nishimura K, et al (1996*). Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO_2 max*. Medicine and Science in Sports and Exercise, 28, 1327-1330.

Tabata reported that interval training of 20 minutes per week (about eight 20-second intervals, with 10 seconds recovery between intervals, 4.5 days per week for 6 weeks) improved anaerobic capacity by 28% (60 to 77 ml/kg).

The subjects performed about eight intervals four days per week. A fifth day per week the subjects first performed 30 minutes of endurance riding and then just four 20-second intervals.

A control group exercised 5 hours per week at moderate intensity (at about 75% of maximum heart rate).

The control group's anaerobic capacity did not change.

VO_2 max increased by 15% (48 to 55 mL/kg/min) in the interval-training group. The control group also improved VO_2 max, by 9%. The starting and ending VO_2 max of the control group was higher than the high-intensity group.

Lindsay[37] reported that replacing moderate-intensity training with six interval sessions over 4 weeks, each session consisting of six to eight 5-minute intervals with 1-minute recoveries, improved 40-kilometer time-trial performance in competitive cyclists by 2 minutes (54.4 vs. 56.4 minutes). This was associated with an 8.3% increase in power (301 to 326 watts), and a 4.3% increase in ramped power (416 to 434 watts). There was no control group.

Weston[38] reported that six interval sessions over 4 weeks, each session consisting of six to eight 5-minute intervals with 1-minute recoveries, improved 40-kilometer time-trial times by 1.2 minutes (57.1 vs. 55.9 minutes). This was associated with a 3.6% increase in ramped power (417 to 432 watts). There was no control group.

[37] Lindsay FH, Hawley JA, et al (1996). *Improved athletic performance in highly trained cyclists after interval training.* Medicine and Science in Sports and Exercise, 28, 1427-1434.

[38] Weston AR, Myburgh KH, et al (1997*). Skeletal muscle buffering capacity and endurance performance after high-intensity interval training by well-trained cyclists.* European Journal of Applied Physiology. 75, 7-13.

Westgarth-Taylor[39] reported that 12 interval sessions over 6 weeks, each session consisting of six to nine 5-minute intervals with 1-minute recoveries, improved 40-kilometer time-trial times by 1.3 minutes (57.1 vs. 55.8 minutes). This was associated with a 12% increase in power (291 vs. 327 watts), and a 5.0% increase in ramped power (404 to 424 watts). There was no control group.

Stepto[40] divided participants into 5 experimental groups. He reported that 4-minute and 30-second intervals were more helpful than 1-, 2-, and 8-minute intervals for 20-kilometer time-trial training. There was no control group.

Laursen and Blanchard[41] reported that four interval sessions over 2 weeks, each session consisting of twenty 60-second intervals with 2-minute recoveries, did not change VO_2 max. Ramped power increased 4.3%. A control group showed no change.

Laursen and Shing[42] reported that 2 experimental groups (G1 and G2) performing roughly 2.5-minute intervals with roughly 3- or 5- minute recoveries twice a week for 4 weeks improved 40-kilometer time-trial time about 5.1% and 5.8% respectively. A third experimental group (G3) performing twelve 30-second intervals improved performance almost as much.

The athletes had been in the off- or precompetition-season and performing low-intensity base training.

Ramped power increased 4.7%, 6.2%, and 3.0% in G1, G2, and G3 respectively.

[39] Westgarth-Taylor C, Hawley JA, et al (1997). *Metabolic and performance adaptations to interval training in endurance-trained cyclists.* European Journal of Applied Physiology. 75, 298-304.

[40] Stepto NK, Hawley JA, et al (1999). *Effects of different interval-training programs on cycling time-trial performance.* Medicine and Science in Sports and Exercise, 31, 735-741.

[41] Laursen PB, Blanchard MA, et al (2002). *Acute high-intensity interval training improves Tvent and peak power output in highly trained males.* Canadian Journal of Applied Physiology, 27, 336-348.

[42] Laursen PB, Shing CM, et al (2002). *Interval training program optimization in highly trained endurance cyclists. M*edicine and Science in Sports and Exercise, 34, 1801-1807.

VO2 max increased in all three groups: 5.4%, 8.1%, and 3.0% in G1, G2, and G3 respectively.

Time-trial power, ramped power, and VO2 did not change in a control group.

Creer[43] reported that 8 sessions of four to ten "all-out" 30-second intervals, twice a week, significantly improved 30-second peak and average power by 6.0% (647 to 690 watts) and 6.0% (515 to 545 watts) respectively.

A control group also significantly improved 30-second peak and average power by 4% (682 to 712 watts) and 3% (550 to 564 watts) respectively.

VO2 max also significantly improved in both groups combined, by 3%. The relative and absolute improvement in high-intensity and control groups was not separately reported.

Taylor-Mason[44] reported that lower-cadence higher-torque intervals were effective in improving time trial performance. In a randomized controlled trial, 10 cyclists in a control group maintained usual training and competing while 12 cyclists in an experimental group replaced part of their usual training with high resistance interval training twice weekly for 8 weeks.

Mean power was 7.6% and VO_2 max 6.6% higher in the experimental group in a 40-kilometer time trial. Times were 2.9% better.

However, the control group worsened, absolute values were not provided in the paper, and non-standard confidence values were chosen (the confidence limit was set at 0.10).

[43] Creer AR, Ricard MD, et al (2004*). Neural, metabolic, and performance adaptations to four weeks of high intensity sprint-interval training in trained cyclists.* International Journal of Sports Medicine, 25, 92-98.
44 Taylor-Mason, AM. (2005). *High-Resistance Interval Training Improves 40-km Time-Trial Performance in Competitive Cyclists.* Sportscience 9, 26-30.

Burgomaster (2005)[45] reported that 4-7 x 30-second sprints repeated six times over the course of 2 weeks was associated with a ≈ 100% improvement endurance capacity at ≈ 80% VO_2 max. VO_2 max did not change.

The control group, with no training intervention, did not improve.

Eight recreationally active subjects were in each group. There were two women in the sprint group; all the rest of the subjects were men.

Burgomaster (2006)[46] reported that 4-7 x 30-second sprints repeated six times over the course of 2 weeks was associated with a 9.6% improvement in 250 kJ time trial times (roughly 16 minutes in duration). The control group, with no training intervention, did not improve.

Mean and peak 30-second power were also improved in the sprint group.

There were eight men in the study and eight men served as controls. The control group was older.

Burgomaster (2008)[47] reported that 4-6 x 30-second sprints three times a week for 6 weeks were as effective in improving VO_2 max as 40-60 minutes of constant load (endurance training) cycling at about 65% VO_2 max five times a week for 6 weeks.

VO_2 max improved about 3 or 4 ml/kg/min, in each group, roughly 7 to 10%.

[45] Burgomaster KA, Hughes SC, Heigenhauser GJF, Bradwell SN, Gibala, MJ. (2005). *Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans.* J Appl Physiol 98; 1985-1990.
[46] Burgomaster KA, Heigenhauser GJF, Gibala, MJ. (2006*). Effort of short-term interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance.* J Appl Physiol 100; 2041-2047.
[47] Burgomaster KA, Howarth KR, Philips SM, Rakobowchuk M, MacDonald MJ, McGee SL, Gibala, MJ. (2008). *Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans*. J Physiol 586.1; 151-160.

Sprint performance improved in both groups (perhaps more in the sprint group). Heart rate at 65% VO_2 max decreased in both groups (perhaps more in the endurance-training group).

There were five men and five women in each group. There was no control group.

Intervals for Different Events Summary

To select the proper exercise intensity for specific events: Intervals may be based on what you do, physiological fitness systems, or what works.

1. One approach is for sprinters to focus on performing intervals at faster and faster speeds (which may require increased recovery periods).

   Kilo and pursuit specialists focus on decreasing recovery between appropriately intense efforts (competitive speeds). Road cyclists employ interval sessions utilizing maximum-intensity sprints performed at the end of longer and more intense continuous riding sessions.
2. A second approach is to prescribe a variety of intervals based on the physiologic systems taxed during the event.
3. A third, bottom-line approach—for 40-kilometer time trialing or improving VO_2 max—is to evaluate the limited number of studies available, and regardless of "reasoning" or physiologic sport science theory, prescribe what has been demonstrated to work: Intervals of about 4 minutes and intervals of about 30-seconds in duration.

Study	Performance Measure	Result			Interval Length	Intensity	Reps	Recovery Length	Sessions /Week	No Weeks	Total Sessions	Number Subjects	Control? Design
		Relative	Absolute	Actual									
Tabata	VO_2 Max Anaerobic Capacity	15%** vs. 9%** 28%** vs. NC	7 vs. 5 ml/kg/min 11 ml/kg** NC	48→ 55 ml/kg/min 53→ 58 ml/kg/m 60→77 ml/kg vs. NC	20 sec	170% VO_2 max	7-8	10 sec	4.5	6	30	7	Control group: 5 hours/wk @ mod intensity Moderately trained non-cyclists.
Lindsay	40K Time 40K Power Ramped Power	3.5%** 8.3%** 4.3%**	2.0 min** 25 watts** 18 watts**	56.4→ 54.4 min 301→326 watts 416→434 watts	5 min	80% RP	6-8	1 min	1-2	4	6	8	No control group. 15% of base mileage replaced by HIT.
Weston	40K Time Ramped Power	2.1% 3.6%*	1.2 min* 15 watts*	57.1→ 55.9 min 417→ 432 watts	5 min	80% RP	6-8	1 min	1-2	4	6	6	No control group. Base mileage replaced by HIT.
Westgarth-Taylor	40K Time 40K Power Ramped Power	2.3%* 12%* 5.0%**	1.3 min* 36 watts* 20 watts**	57.1→ 55.8 min 291→327 watts 404→ 424 watts	5 min	80% RP	6-9	1 min	2	6	12	8	No control group. 15% of base mileage replaced by HIT.
Stepto	40K TT	NS			8 min	80% RP	4	1 min	2	3	6	4	No control group. 5 experimental groups. 15% of base mileage replaced by HIT.
	40K TT	2.8%*			4 min	85% RP	8	1.5 min	2	3	6	4	
	40K TT	NS			2 min	90% RP	12	3 min	2	3	6	4	
	40K TT	NS			1 min	100% RP	12	4 min	2	3	6	4	
	40K TT	2.4%*			30 sec	175% RP	12	4.5 min	2	3	6	4	
Laursen, Blanchard	Ramped Power VO_2 Max**	4.3%* vs. NC Neither Changed			1 min	100% RP	20	2 min	2	2	4	7 vs. 7	Control group.

Table continued next page

Study	Performance Measure	Result			Interval Length	Intensity	Reps	Recovery Length	Sessions /Week	No Weeks	Total Sessions	Number Subjects	Control? Design
		Relative	Absolute	Actual									
Laursen, Shing	40K TT Time Ramped Power VO_2 Max**	5.1%* 4.7%* 5.4%**			≈ 2.5 min	≈ 96% RP	8	≈ 5 min	2	4	8	8	Control group. 3 experimental groups, listed in table in order (G1, G2, G3). Subjects blinded. Performance-matched groups. 20% of G1 and 10% of G2 subjects dropped. 64% of prescribed workouts completed. Base mileage continued.
	40K TT Time Ramped Power VO_2 Max**	5.8%* 6.2%* 8.1%**			≈ 2.5 min	≈ 96% RP	8	≈ 3 min	2	4	8	9	
	40K TT Time Ramped Power VO_2 Max*	4.4%* 3.0%* 3.0%*			30 sec	175% RP	12	4.5 min	2	4	8	10	
	40K TT Power Ramped Power VO_2 Max	0% NS -1.1% NS 0.8% NS			This is the control group.							11	
Creer	30-Sec Peak Power 30-Sec Mean Power VO_2 Max	6.0%* vs. 4.0%* 6.0%* vs. 3.0%* 3%* Combined	43 vs. 30 watts 30 vs. 14 watts NR	647→690 vs. 682→712 watts 515→545 vs. 550→564 watts NR	30 sec	"All-out sprints"	4-10	4 min	2	4	8	10 vs. 7	Control group. Base mileage continued. Absolute results not reported.
Taylor-Mason	40K TT Time 40K Mean Power Ramped Power VO_2 Max	-2.3% vs. 0.6% 6.4% vs. -1.1% 6.1% vs. 4.1% 4.6% vs. -1.9%	Not reported		Session: 3 to 22 min Week: 25 to 55	40 to 80 rpm Highest gear to maintain cadence	5-6	1 to 5 min	2	8	16	12 vs. 10	Control group. Experimental group partially substituted high-resistance training. Non-standard statistics for P<0.1.

Table continued next page

Study	Performance Measure	Result			Interval Length	Intensity	Reps	Recovery Length	Sessions /Week	No Weeks	Total Sessions	Number Subjects	Control? Design
		Relative	Absolute	Actual									
Burgomaster (2005)	≈ 80% VO2 max TT* VO2 Max	96%* vs. 10% ΦΔ	25 vs. −2 min NR	26→51 vs. 18?→20? min NR	30 sec	"All-out sprints"	4-7	4 min	3	2	6	10	Control group values estimated from graph.
Burgomaster (2006)	250 kJ TT** 30-Sec Peak Power* 30-Sec Mean Power*	9.6%** ΦΔ 5.4% vs. NR 8.7%* vs. NR	25 vs. −2 watts 52 vs. NR watts 68 vs. NR watts	247→272 vs. 231→229 watts 964→1016 watts 786→854 watts	30 sec	"All-out sprints"	4-7	4 min	3	2	6	10	"Sprint" interval training group.
Burgomaster (2008)	VO_2 Max* HR at 65% VO_2* Wingate Power*	7.3% 5.6% 17%	3 ml/kg/m 9 bpm	41→44 160→151	30 sec	"All-out sprints"	4-6	4.5 min	3	6	18	10	"Sprint" interval training group. Based on previous work, Wingates are probably 30 seconds in duration.
	VO_2 Max* HR at 65% VO_2* Wingate Power*	9.7% 8.2% 7%	4 ml/kg/m 13 bpm	41→45 157→144	40-60 min	≈ 65% VO_2 max	1	NR	5	6	30	10	Endurance training group. No control group.

Table 20. Summary of cycling-related interval studies. Sources are cited in the text.
NC = No change. RP = Ramped power. ≈ = Approximately. NR = Amount not reported, but significant.
*** Significant improvement, P< 0.05. ** Very significant improvement, P < 0.01. NS = Not significant.**
Note: Due to the exponential increase in power required relative to speed, percent improvements in power are greater than percent improvements in time.

Interval Theory Summary

- Interval training allows a greater volume of high-quality work than can be achieved by continuous work.
- Conventional wisdom: Interval training at or above sport-specific intensities is valuable for improving fitness for nearly all cycling events.
- Unless intervals are performed at a cadence, heart rate, power, or torque level above that of continuous work, interval work is unlikely to be of more benefit than continuous work.
- Select interval length, intensity, repetitions, and recovery length.
  - A variety of interval lengths from 5 seconds through 30 minutes will train different fitness systems to improve cycling performance.
  - Interval intensity may be based on cadence, heart rate, power, or torque.
  - Intervals within intervals (surges within hard-steady efforts) may also have value.
- Increase interval demands as fitness improves.

Practical Workouts

- The *Standard* and *Rapid HIT* programs outlined in Sections 4 and 5 of this book include all of these interval lengths and intensities.
- Six 4-minute intervals, with 3-minute recoveries, are probably the most productive single type of interval for most cyclists. For more information about such intervals, see *3- to 5-Minute (VO2) Intervals* on page 115.

Part 3: Practical Training Tips

How Hard is Hard?

Beginners' Info

At first we "just go riding." As we learn more about cycling and about training, we hear about interval work: Hard periods of work interspersed with easy recovery periods. Much of what we read suggests that interval work is a method of improving fitness rapidly. Is this true? Is interval work necessary?

Most studies have shown that the most important predictor of fitness is time spent training—whether it is miles run or miles cycled.

In any sport, most early gains come relatively easily. Gains at the elite level require a lot of time and effort for relatively little reward. For most beginners, what is required is building a good solid base from *time* spent training rather than from *intensity* of training.

Riding 100 miles per week will gain more than half of one's potential in cycling fitness. Though world-class athletes may train 400 to 600 miles a week, local competitive racers will be competent with just half that amount of training.

Interval training helps improve fitness mostly in athletes who are already performing a sizable volume of training.

An exception: If your events are sprint events—50- to 100-meter/yard dash runs or sprint finishes in cycling criteriums or track events—then you'll need to develop anaerobic fitness that comes from strength training and anaerobic (short, less than 1-minute) intervals.

For most athletes, no more than one-third of training sessions should be high intensity, defined as a power output, effort, or pace 10% or more higher than steady-distance intensity.

Within high-intensity training sessions, typically less than one-third of the time is actually spent at high intensity—the rest is made up of warm-up, cool-down, and recovery periods.

About half of all training sessions should be easy. The rest are of moderate intensity.

Many athletes find that hard work, in the form of intervals, adds to the variety of their training, helps prevent boredom, is enjoyable, and does improve fitness. Unscheduled fun intervals—fartlek training—often occur on group cycle training rides or runs/walks. If you are going to consider adding formal intervals, here is a rough guide to interval length, interval intensity, and repetitions (number of intervals per session).

Interval Length	Relative Pace %	Repetitions
10 minutes	100	3
8 minutes	107	4
4 minutes	113	8
2 minutes	120	12
1 minute	133	12
30 seconds	233	12

Table 21. Interval length, speed, and repetitions—relative to speed maintained in a maximum 30 to 60 minute effort:

A variety of interval lengths and intensities round out fitness. For most athletes, the most productive type of interval is the 3 to 5 minute interval. Such intervals are performed at a speed about 10 to 15% above 20-kilometer cycling race-pace speed.

Remember to recover between intervals—normally for a few minutes. As a beginner, do intervals no more than once a week. Once you perform intervals more often than that, you are no longer a beginner!

How Hard is Hard?

Elite Interval Blocks

A minority of coaches block together up to three days of interval training in a row to maximally overload the athlete, seeking the maximum training stress adaptation. These coaches stress the need for a similar number of days in a row of recovery. Examples of half a dozen possible 3-week interval block series (mesocycles) are given in Table 22 below.

This information may be of interest, but block interval training is not something you should necessarily attempt. Such programs are unsuitable for almost all but professional athletes under the guidance of a coach.

	Strategy	Week #	Workout #1	Minutes Work	Workout #2	Minutes Work	Workout #3	Minutes Work
Aerobic-Endurance	Endurance training	1	3x30	90	2x30	60	4x15	60
(Lactate threshold)	Submax intensities	2	4x30	120	3x30	90	2x30 or 3x20	60
		3	3x30	90	2x30	60	3x20	60
Threshold	As hard as possible	1	5x8	40	4x8	32	3x8	24
(Max steady-state, TT intervals)	to complete interval	2	6x10	60	5x10	50	5x8	40
		3	6x8	48	6x8	48		
Anaerobic-Endurance	As hard as possible	1	7x3	21	6x3	18		
(VO_2 intervals)	to complete interval	2	8x4	32	8x3	24	7x3	21
First mesocycle		3	8x3	24	7x3	21		
Anaerobic-Endurance	As hard as possible	1	7x4	28	7x3	21	6x3	18
(VO_2 intervals)	to complete interval	2	7x4	28	7x4	28		
Second mesocycle		3	8x3	24	7x3	21		
Anaerobic-Power	As hard as possible	1	7x15”	1.75	7x15”	1.75	6x15”	1.5
	to complete interval	2	7x20”	2.3	7x20”	2.3		
		3	8x15”	2.0	7x15”	1.75		
TT Event (2K and longer)	↓ Relief interval	Target pace = 105–110% of current pace		Divide target pace into 4 to 8 segments		↓ Recovery in successive workouts		

Table 22. Examples of interval mesocycles—3-week blocks.

Focus & Breathing

Focus has intensity, width, direction, and relevance.

Athletes can learn to intensify, narrow, internalize, and associate their focus and thereby improve their performance.

Learning focused, coordinated breathing is one of the best tools to achieve this gain.

Focus

Focus, or attention, may be *strong* or *weak*, *external* or *internal*; *narrow* or *wide*; *associated* or *dissociated*.

External focus is attention directed outside the body. Internal focus is attention directed inward.

Narrow focus is restricted; wide focus, like peripheral vision, takes in a large field of view.

Beginners frequently *dissociate*—separate what they are thinking about from what they are doing. For example, beginners may think about favorite restaurants while racing.

Elite athletes *associate*. They invariably try to keep from dissociating.

The harder the effort, the more important it is to be able to keep a strong, narrow, internal, associated focus.

Studies show that elite time trialists do precisely this: they keep a strong, narrow, internal, and associated focus—they concentrate within—not on the flowers on the hillside, upcoming television shows, or the conflict in the Middle East.

Although studies show that elite athletes are more focused than beginners are, it is something elite athletes learn. If beginners learn focus techniques, they benefit as well.

Shifting Focus

In many events, it is important to be able to shift focus. For example in a road race, it is important to have a wide, external focus in order to see competitors up the road or falling behind, and then have a narrow, internal focus in order to work harder to make the break or leave others further behind.

Riding recreationally along the roadway, it is important to shift focus: To pay narrow attention to potholes just a few feet ahead as well as to widely notice, for example, the flow of traffic, stop signs, pedestrians, opening car doors, animals, and other riders.

Riders who disassociate while riding, thinking about their jobs or family arguments may be more likely to have accidents.

The ability to shift and hold focus is a critical element that separates champion athletes from beginners.

Although as efforts increase in intensity elite athletes increase the intensity of their focus, shift their focus inward, and associate—they also maintain flexibility in width and direction.

For example, in track pursuit (an effort of several minutes' duration), in addition to focusing on their effort, athletes must have an external focus on their line—they must make sure that they do not drift upward on the track, traveling farther.

Rhythmic Effort

Got rhythm? Watch video footage and listen to commentary of time trialists or climbers narrated by the well-known voice of cycling, Phil Liggett, and you will hear about riders "getting into a good rhythm" or "not in their rhythm."

Steady-state hard effort demands a good rhythm. Such a rhythm is part of all aerobic endurance sports such as swimming, running, rowing, marching.

Humming or singing a song is one way to keep rhythm—hence soldiers' marching songs. Counting pedal strokes is another.

Music

Music is used in many aerobics and spin classes—and this may be its best use.

Many riders use music during their stationary trainer workouts.

Music is most suitable for moderately-high level, rhythmic, aerobic work. It helps athletes increase arousal and focus on their work.

Sophisticated set-ups allow music to be played at variable rates—allowing instructors to coordinate the music's beat with the exercise rhythm.

However, music may not always coordinate with the best cadence for any given rider, and is generally not suitable for the highest intensity work that requires an internal focus.

Listening to music while riding on the road or trail is not safe. Racers also need to train without music so that they can learn self-monitoring and pacing for racing.

Focus & Breathing

Focus on effort and the self-monitoring of effort are characteristics of elite athletes.

Breathing is one of the cardinal self-monitoring focus tools.

Of course, you breathe whether you think about it or not: from as little as 10 times per minute at rest to more than 60 times per minute at maximal effort.

Breathing technique is important in hard, steady efforts. It is not important when you are noodling—riding slowly. It may not be applicable when you are constantly changing efforts, as in criteriums or when you are making a maximum effort, as in sprinting.

Breathing technique is also important when you want to keep to a pace, even if it is not at a high threshold. By breathing regularly, your pace will stay steady as well.

Focused breathing is also well known to help when you face a crisis—whether related to pace, a cramp, or a crash. It helps get you back on track. After all, think how many women in labor have been helped with the focused breathing techniques of Lamaze.

Focus & Breathing Helps Beginners

Although champion athletes have been the most closely studied, focus is just as important for beginners. It is very helpful for all riders when climbing long steady hills.

Almost all of riders will benefit from learning to breath and count even if it only helps them get to the top of the next hill before they know it.

Why Focused Breathing Works

Focusing on breathing helps us draw on our reserves and get closer to reaching our potential.

Consider an analogy: If you can normally perform about 20 push-ups, performing 10 is a piece of cake, and you do not need to focus on technique. However, if you are trying to do 21, it is a different story. You need focus. You need to count. You do not want outside distraction, people talking to you. If you focus, if you count each push-up, you can get closer to the limit of your potential.

Studies of elite athletes show that they focus on how their bodies are working, that they develop a sense of pace, and that they constantly seek to test their pace and efforts.

Beginners tend to focus more on the outside environment and factors not within their control. Focusing on breathing is a key to self-monitoring of effort and developing the ability to work to your maximum potential.

How Often Should You Breathe?

To some extent, you do not have much choice. It is not that one can say you should breathe this many times a minute and just do it. For any given effort, there will be a limited range of what is comfortable.

You can vary the frequency of your breathing by modifying the depth of your breathing.

Notice your breathing and co-ordinate it with the pedal stroke of your legs. This is the key to unlocking a good rhythm.

For many riders, working at about 75% of maximum heart rate, breathing frequency will be about 30 times per minute. For many riders, working at 85^{+}% of maximum heart rate (near VO_2 max), breathing frequency will be about 60 times per minute.

Cadence, or number of pedal strokes per minute, will vary with the type of riding.

Timing your breaths with pedal strokes will therefore vary depending upon how hard you are working and the type of riding you are performing.

For many riders, climbing at a cadence of 60 rpm, breath timing will be once every two pedal strokes at 75% of maximum heart rate, once every pedal stroke and a half at 80% of maximum heart rate, and once every stroke at 85^{+}% of maximum heart rate.

For many riders, at maximal road time-trial pace, breath timing will be once every stroke and a half. Since cadence will be about 85 rpm, this will translate into a breathing rate of about 55 times per minute at 90% of maximum heart rate.

Concentrate on Breathing Out

When you concentrate on breathing, concentrate on breathing out—exhaling, rather than breathing in—inhaling.

Spend the same or more time breathing out than breathing in.

Use Your Mouth

At high-aerobic intensity, the nasal passages restrict airflow. Nasal dilators have not been shown to be effective.

Consider Purse Breathing

Slightly narrowing your lips when breathing may improve air exchange for some riders, yet not overly restrict airflow.

In many riders, the breathing passages may partially collapse or constrict.

The positive pressure exerted through the breathing passages may help keep them from collapsing and improve air exchange.

Learn to Belly Breathe

Breathing with your diaphragm and expanding your abdomen may increase lung capacity, improve relaxation, and use less energy.

It also uses different muscles than the standard chest breathing, and so may be helpful to help prevent you from tiring from prolonged respiratory muscle work.

Learn to belly breathe lying flat on your back with a book on your abdomen. As you breathe in, the book should rise.

Alternate Stroke Emphasis

If you are breathing once every pedal stroke and a half, you will naturally alternate emphasis on the left and right leg.

If you breathe once every stroke, your emphasis may be on one leg. Consider breathing once every stroke on your left leg for 10 strokes, then once every stroke on your right for 10 strokes, then your left, and so on.

By varying your emphasis, you make the exercise more interesting. Shifting your focus reduces boredom. It also prevents fatigue or stress on one side vs. the other.

Change Your Breathing

It is not as if you should always have the same rhythm. Consider the analogy of music. It may have a basic rhythm or beat. However, this need not stay constant for the whole composition. Sometimes it shifts to another rhythm, or a third, only to return to the original later.

It is the same thing with riding. Suppose you are climbing, breathing every stroke and a half. As you get near the summit, you can change your rhythm to every stroke as you pick up the pace to surge over the top.

Hyperventilation

Caution: Overbreathing can be a problem. Anxiety can cause hyperventilation; in some athletes, the reverse is true: overbreathing can increase anxiety.

The Work of Breathing

Focused, coordinated breathing does something else: It reduces the work of breathing.

At maximal work levels, the muscles of breathing can use up to 20% of the energy and oxygen you are producing and need. Energy you save by improving breathing economy can be used by your legs to get you down the road.

Exercises for Focused Breathing

Let us face it, not all of us were born with rhythm. Perfecting breathing technique takes practice.

Efforts on a stationary trainer can be precisely controlled. Stationary trainer workouts can provide an excellent place to start learning breathing techniques.

For example:

1. During a steady 75% to 80% of maximum heart rate effort at 90 rpm, focus on exhaling every two pedal strokes.
2. Pick up the pace about 10% and concentrate on breathing every stroke for about 15 seconds.
3. Back off to steady-state 75% to 80% of maximum heart rate effort again. Focus on exhaling every two pedal strokes again, this time counting strokes of the alternate leg.
4. Work at about 85% of maximum heart rate effort at 90 rpm and focus on an every-stroke-and-a-half rhythm. Breathe once every second.

The Arnie Waltz

Those of you with musical talent may have instantly understood the breathing-every-pedal-stroke-and-a-half concept—that results in alternate stroke emphasis and a breathing rate of about 55 times per minute when time trialing.

Think of it perhaps as a waltz—you know, the ONE-two-three, ONE-two-three, ONE-two-three, ONE-two-three rhythm.

Each time you pedal, with the left or the right leg, count. Each time you have a count of ONE, breathe out.

Since, as suggested above, you spend more time breathing out than breathing in, it is: (Exhale) ONE, two, (inhale) three. Repeat.

It is easy—now you are doing the Arnie Waltz!

Picking Up the Pace

Want to go a little faster? Try focusing on your breathing, getting a rhythm. Then slightly increase your breathing rate. Let your cadence increase with your higher breathing rate. Watch your speed computer. You will go faster!

Summary

Athletes can learn to intensify, narrow, internalize, and associate their focus and thereby improve their performance.

Like fitness training, breath training requires practice.

With practice, breathing techniques will become second nature, automatically improving focus, training, and race performance.

Isolated Leg Training

What if I told you there was a simple method of bicycle training that would improve almost all aspects of fitness? A method that would help strength, spin, leg speed, anaerobic power, neuromuscular coordination, focus, and breathing? A method so powerful that in training hundreds of athletes, I have never met one who did not benefit and see improvement within a few training sessions?

You would want to try this method, I hope. It is called isolated leg training, ILT, or one-legged riding.

What You Do

Unclip from one of your pedals. Ride with one leg, then alternate and ride with the other. If riding on the road, dangle your inactive leg to one side, or find a safe place to rest your heel on your chainstay or seatstay, away from your spokes.

On a stationary trainer, you can rest your inactive foot on the back of your trainer, on a side support (a box or a stool), in the drop of your handlebar, or in your waterbottle cage. Work up to three-minute intervals. Work up to four repetitions.

Work On Strength

In my experience, high-load 50 to 60 rpm ILT is the best method of improving cycling-specific strength.

For some proof, see Figure 39 and Table 8 on page 60.

However, do not use high loads to start. Take several sessions to adapt to this exercise.

It is easiest to perform this work on a stationary trainer or on a hill (up to about 6% grade).

Choose a moderately-hard gear, one that you can only pedal between 50 and 60 rpm.

Since you are working only one leg, your heart rate response will probably not be high. You will be working on your muscles, not on your cardiovascular system—isolating the muscle component of fitness.

With moderate loads, you can focus on difference parts of your stroke. Sometimes focus on pushing down. Sometimes focus on pushing forward. Sometimes focus on pulling up. Sometimes focus on pulling through, or pulling around.

After adapting to moderate loads, choose a harder gear.

Pedaling smoothly does not necessarily result in the highest average torque or power. Pedaling smoothly also means that you are not working your most powerful muscles to their potential. A harder gear will specifically strengthen your quads and glutes—the most important cycling propulsive muscles you have.

You may be able to perform high-power ILTs with so much force that you can push yourself up off the saddle. It helps to stabilize and anchor yourself with your arms. Pulling with your arms may allow you to work harder. If you are performing a left leg ILT, pull more with your left arm. Elite athletes may perform ILTs with such high torque that they may require two hands on same side of the handlebar to keep in the saddle.

Road racers and mountain bikers work with their hands on the tops. Time trialists, criterium riders, and track specialists work more with their hands in the drops.

When performed in an easy or moderate gear at 70 to 90 rpm, this exercise tends to work the hip flexors (pulling up muscles) more.

Work On Spin and Leg Speed

Why do riders bounce at high rpm? It is because they do not send a neurologic signal to their muscles to stop pushing down at the bottom of the pedal stroke fast enough. A leg that is still pushing down at the bottom of the stroke while the pedal is already coming up forces the rider off the seat.

Bouncing here is not a question of too high a saddle, leg strength, aerobic or anaerobic fitness. It is a question of neuromuscular coordination. It is a skill.

This skill comes from neuromuscular practice.

Choose an easy gear. If you have a heart-rate monitor, choose a gear that allows you to ride at less than 65% of maximum heart rate. If you have a power meter, choose a gear that allows you to ride at less than 50 watts.

Ride with one leg at a cadence between 80 to 90 rpm.

Pedal stroke will improve.

Leg speed will improve—even for two-legged cadences at more than twice this rate.

Read more about neuromuscular fitness on page 16.

Work On Different Positions

Different bicycle positions work the muscles differently.

It is easiest to perform ILTs when the hands are positioned on the tops of the handlebars.

After you progress to performing three-minute intervals on the handlebar tops, alternate position to the handlebar drops in the middle minute of the intervals.

Pacing, Focus, and Breathing

ILTs are excellent exercises to help improve pacing. It is easy to mistakenly work too hard initially and not be able to maintain cadence for the prescribed duration.

Athletes operating near their time trial threshold in steady, hard efforts often perform better by focusing on their own efforts, listening to their bodies' rhythms.

Intense, narrow, internal, and associated focus improves performance for almost all athletes.

Isolated leg training is an ideal exercise in which to start counting strokes or practice rhythmic breathing.

Then extend the coordination of counting, breathing, or other rhythmic action to time trialing or climbing with both legs.

Read more about focus and breathing on page 107.

Give ILT a Try

One-legged riding helps every type of cyclist—from mountain biker to sprint specialist to RAAM rider.

Start with two or three repetitions of one minute for each leg, and build up to three or four repetitions of three minutes over six to ten training sessions.

Perform ILT training once or twice a week.

You can mix 50 to 60 rpm high-load and 80 to 90 rpm low-load work in the same session.

After just six training sessions, I am confident that you will notice a benefit.

If you want to continue training with one leg, give ILT a rest for a week or two, and then build up to another peak over 3 to 4 weeks.

Now give ILT a rest. Remember, it is not during training, but during the recovery from training that we improve fitness.

Allow a month or two before entering another 6-week ILT phase.

Four ILT phases a year are probably best for maximizing gains and minimizing boredom or staleness.

HIT Programs

Isolated leg training is incorporated into both the standard and rapid HIT programs found in Parts 4 and 5 of this book.

Read more about ILT protocols on page 136 and 149.

Aerobic Training

Aerobic capacity and aerobic endurance are important cycling fitnesses.

Aerobic Capacity

Aerobic capacity is the ability to work using oxygen in combination with fats and carbohydrates as fuel sources to produce energy.

At low-aerobic levels, fat is the primary fuel source. At high-aerobic levels, glycogen—stored carbohydrate in muscle—predominates as a fuel source.

Aerobic Endurance

Aerobic endurance is the ability of the body to perform aerobic work over long periods. This is important in sustained efforts—in time trialing or in long hill climbing.

To improve aerobic endurance one must improve the quantity or quality of components of this system.

Aerobic endurance involves oxygen transport from the air we breathe to the chemical factories of the body that burn fats and carbohydrates in combination with oxygen for fuel.

This fitness system includes the heart, lungs, circulation, cell transport systems, and the cells' chemical factories—the energy-producing mitochondria.

Aerobic Training Principles

Aerobic training requires the rhythmic action of large muscle groups, as in cycling or running. Vigorous video game play using only smaller hand muscles can never place enough demands on the body to be aerobic.

Aerobic training begins at about 66% of an individual's maximum heart rate.

An increasing workload is required to stimulate aerobic training as an individual becomes fitter. Consequently, aerobic training should be progressive:

Since the body is constantly adapting, the intensity of workouts must be increased until an individual's genetic aerobic potential is reached.

For the very fit, training at rates higher than 93% of maximum heart rate will cause anaerobic systems to kick in, allowing fewer aerobic repeats. For the less fit, anaerobic systems may take over at heart rates as low as 80% of maximum.

Besides reaching your aerobic capacity, you can train to increase the length of time over which you can work at or near this level.

Intensity, Duration, Frequency

As stated above, aerobic training begins at about 66% of an individual's maximum heart rate.

To maximally train the aerobic system, riders need high-level aerobic work—loads that result in 80% to 90% of maximum heart rate.

Once you have built a base of a thousand miles or more over a few months, you can aim to train at this intensity two or more times per week. Aim for a cumulative total of about two hours per week.

Endurance may be improved by training at lower intensity levels, but maximal oxygen uptake may not increase.

Spending more time training at high-aerobic levels may be productive during some training phases. During these phases, riders may train at high-aerobic levels up to six hours per week.

There is a limit as to how much time riders can spend at high-aerobic levels because there is a limit to high-aerobic energy sources. Intramuscular glycogen is a limiter.

There is also a neurohormonal limiter. High volumes of high-aerobic work should not be performed routinely because of overtraining risk.

Racers need training at 86% to 92% of maximum heart rate to reach the limits of their aerobic potential. Training near this level overlaps with anaerobic training at times; this is threshold training. When training at such very-high aerobic levels, reduce the overall volume of aerobic work.

Aerobic fitness may begin to be lost in as little as one to two weeks; training regularity is important. Accumulate thirty minutes of aerobic training twice a week for maintenance.

High-level aerobic training is not required for everyone. Riders are commonly able to complete a hilly century successfully without maximizing their aerobic training.

Value of Interval Training

As elsewhere noted, unless intervals are performed at a cadence, heart rate, power, or torque level above that of continuous work, interval work is unlikely to be of more benefit than continuous work.

One may exercise longer at the limits of high-aerobic metabolism by performing intervals rather than by continuous training. There *is* evidence that interval training is helpful in high-level aerobic training

Length of the Aerobic Interval

High-level aerobic intervals should be long enough to reach maximum oxygen uptake in most of the intervals, and short enough to minimize fatigue.

Because experimental results are inconclusive regarding the benefits of short (15–30 seconds) and long (up to 5 minutes) intervals for aerobic training, a variety of training intervals is recommended.

My favorite interval length is 3 to 5 minutes. This is because it is relatively easy to perform such intervals effectively.

To train aerobically, intervals shorter than three minutes require similarly short recoveries—otherwise aerobic demands may be low or work may be performed anaerobically.

Mild exercise during rest intervals (heart rate 100–120 bpm) hastens recovery. Keep your legs moving!

For more information about high-level aerobic intervals, see *3- to 5-Minute (VO2) Intervals*, next, on page 115.

Workout Guidelines

3- to 5-Minute (VO_2) Intervals

Athletes and coaches commonly think of intervals as 3- to 5-minute efforts. These intervals are perhaps the most common length performed.

Three to 5-minute intervals are also called VO_2 intervals because they are thought to specifically train the physiologic systems that result in improving the body's ability to maximize oxygen uptake.

Maximum oxygen uptake occurs at levels below maximum workload. Said differently: Although you will be working and breathing hard, you do *not* need to work "as hard as possible" to work at you aerobic maximum.

Shorter intervals may also train VO_2 max if recoveries are relatively short. Such intervals are harder to perform correctly.

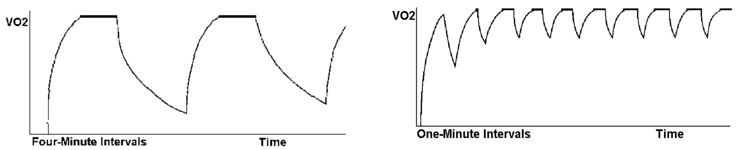


Figure 44. Eliciting maximum oxygen uptake. The left figure is of 4-minute intervals with equal-length (4-minute) recovery. The right figure is of 1-minute intervals with 30-second recoveries.

Maximum oxygen uptake occurs at the top, flat sections of the curves. Maximum oxygen uptake occurs during roughly the last half of the 4-minute intervals, regardless of the length of the recovery. Unless recoveries are short, maximum VO_2 will not occur with 1-minute intervals. Note that in the figure, it is only after the third 1-minute interval that VO_2 max is achieved.

For most bicycle riders, 3- to 5-minute intervals are the basic, most helpful type. As riders become fitter, a variety of intervals will be best.

Intervals can be performed on the road, on the track, or on a stationary trainer. The stationary trainer provides the most controlled environment for intervals (although for track racers, the velodrome provides the most specific).

If you control the settings of your stationary trainer (tire pressure, roller resistance, gearing) your cadence computer effectively becomes an intensity meter, reflecting your workload.

Pace

Use the first interval or two of a six-interval set as part of your warm up.

Many coaches simplistically say: Perform each interval as hard as you can to finish the interval. Stop when your next interval cannot be performed at the same intensity.

This may sound good to some, but is not an accurate description of how intervals are best performed. If you truly perform a single interval at maximum intensity, it is simply not possible to perform another at the same intensity. If you ride a kilometer (about 1 minute) or pursuit-distance (3 to 5 minutes) event flat out, you cannot perform another effort at the same intensity until another day.

For 3- to 5-minute intervals, perform each minute of each interval at a slightly higher intensity than the preceding minute. Perform each succeeding interval at a slightly higher intensity level than the preceding interval. In other words, negatively pace the intervals.

For example, increase cadence 2 to 3 rpm each minute of each interval. Start each successive interval 1-2 rpm higher than the previous.

The overall pace will rise 5% to 10% during each interval; the overall pace of the last interval will be 5% to 10% greater than the first.

Heart rate will rise during the course of each interval. Heart rate will be higher for each succeeding interval.

Workload generally rises between the square and the cube of pace, depending upon the trainer or workout venue. Therefore, workload will rise between 10% and 30% during the course of each interval and for each succeeding interval.

Riders who perform intervals at about 250 watts will typically increase power about 15 watts each minute, and interval starting power about 10 watts for each interval.

This pacing method has many advantages. Among them:

1. The blood to working muscles is not fully flowing after most warm-ups. The first interval or two allows precapillary sphincters to open and blood flow to increase. This allows more oxygen to reach the tissues, and more lactate to be carried away.
2. The total amount of work that can be performed during the intervals with pacing will be near maximum. More work can usually be performed following this approach than can be performed by working each interval and each minute of each interval at the same intensity.

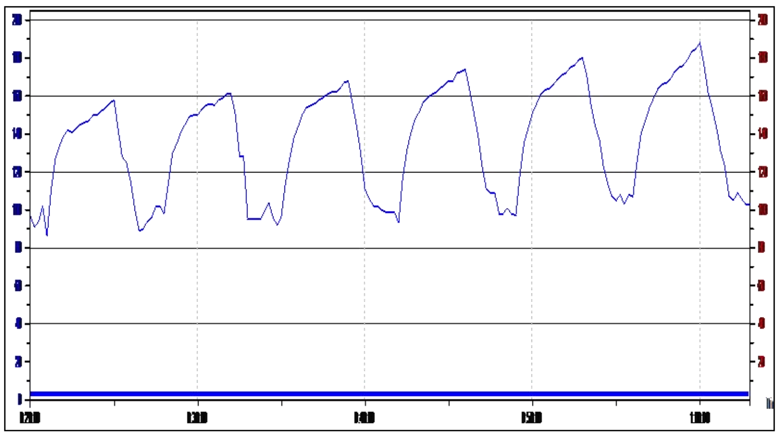


Figure 45. Six 4-minute intervals. Heart rate recording from a stationary trainer workout. Corresponding cadences and power outputs are given in Table 23 below.

Intervals are hard work. Performing each minute of each interval at "maximum intensity" is not only physically unreasonable; psychologically it is overly harsh for most riders. Athletes often break down and are unable to continue such programs.

Allowing pacing and a transition to maximum intensity is physically and psychologically sensible.

Try this a time or two: Perform the fifth of six 3- or 4-minute intervals with the same gear and cadence (power output) as the first interval. Feel a lot easier than the first interval? Almost certainly. This shows the value of pacing and warming-up into intervals.

In general, you can drink during the recovery after the first couple of intervals, but not after the third or later intervals. If you can, perhaps you are not going hard enough—because most hard-working athletes cannot.

Gear	39/13			
Cadence	80 to 110 rpm			
Heart Rate	85^{-}% to 95^{+}% of maximum heart rate			
Interval #	**Cadence Each Minute**	**% Max HR At End of 3 Mins**	**Average Watts**	**Average Watts/Kg**
1	83/86/89/92	81	250	3.8
2	85/88/91/94	83	270	4.1
3	87/90/93/96	87	280	4.3
4	88/91/94/97	90	295	4.5
5	89/92/95/98	93	305	4.7
6	90/93/96/100	97	315	4.8

Table 23. Typical gearing, cadence, heart rate, and power: Six 4-minute intervals. The corresponding heart rate recording is shown in Figure 45 above.

Lactate Suffering Factor (LSF)[48]

As previously stated, pacing as described above to allow slightly increasing workloads within and between each interval results in the same or more total work with less perceived effort.

[48] LSF is a conceptual term I coined to help athletes understand one aspect of the physiologic basis of pacing.

Work Minute	**Even Splits** Pace%	HLa	**Positive Splits** Pace%	HLa	**Negative Split** Pace%	HLa
1	100	10	105	12	95	8
2	100	11	100	13	100	10
3	100	12	95	13	105	12
4	100	13	90	13	110	13
Time	Even		Worse		Better	
LSF	46		51		43	

Table 24. Lactate Suffering Factor (LSF). 4-minute strategies
Pace%: Percent of even split pace. HLa: Blood lactate level resulting from workload at end of selected minute.

Table 24 represents a concept of blood lactate levels as a result of work performed at the end of each minute of 4-minute intervals performed with different pacing strategies. (There are no actual data in the scientific literature. Although intramuscular lactic acid may be responsible for a burning sensation, “lactate suffering factor” is a theoretical concept.)

With even or positive pacing, lactate levels rise quickly. With negative splits, the initial level is less dramatic.

The sum of minute-by-minute lactate represents a “suffering” factor.

Once again, the philosophy: The greatest amount of work with the least perceived effort.

Power Output

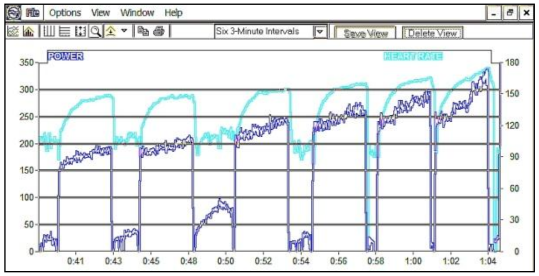
As previously noted in the discussion *More High-Intensity Training* on page 88, unless the interval is performed at a cadence, heart rate, power, or torque level above that of continuous work, interval work is unlikely to be of more benefit than continuous work.

In order to be effective, the majority of 3- to 5-minute intervals must be performed at workloads above 30-minute time trial pace.

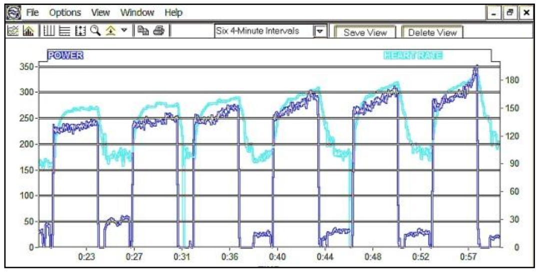
Although not effective in increasing maximum aerobic capacity, intervals performed below 30-minute time trial pace may:

- Help adaptation to high-intensity work
- Build a bigger base/increase overall training volume
- Increase general aerobic or muscular endurance
- Assist in rehabilitation
- Provide variety, reduce boredom
- Provide workout structure, or
- Improve neuromuscular technique or skill.

Figure 46 shows less effective and more effective interval work. The downloads are of an athlete whose 30-minute time-trial average power output is 250 watts, and whose maximum heart rate is 190 beats per minute.



Interval	End of Interval Power	Heart Rate (% Max)
1	188	149 (78)
2	208	148 (78)
3	244	154 (81)
4	264	159 (84)
5	288	165 (87)
6	315	174 (92)



Interval	End of Interval Power	Heart Rate (% Max)
1	241	150 (79)
2	256	152 (80)
3	272	161 (85)
4	294	169 (89)
5	304	176 (93)
6	323	183 (96)

Figure 46. Less effective (top) and more effective (bottom) intervals. PowerTap download of six 4-minute intervals on the top, six 3-minute intervals on the bottom. Heart rate, upper line, turquoise; power, lower line, blue. Same athlete, 30-minute time trial power pace is 250 watts; maximum heart rate is 190 beats per minute. See the discussion in the text.

In the less effective interval work shown on the top recording, only at the end of the fourth interval does power output exceed time-trial average power output of 250 watts, and only in the last two intervals does power average more than 250 watts.

In the more effective interval work shown on the bottom recording, power output reaches 250 watts at the end of the second interval, and averages well over 250 watts for the last four out of six intervals.

Figure 47 shows suboptimal intervals in an athlete who fails to maintain pace, perhaps because he starts out too hard, lacks concentration, or is fatigued.

Although a gradual increase in intensity is recommended during each interval, this athlete does more: he surges at the end of most intervals. Although surging *can* be effective for certain kinds of training, here the athlete admits to surging in order to see higher finishing numbers and note them in his log, rather than focusing on higher average power output throughout each interval.

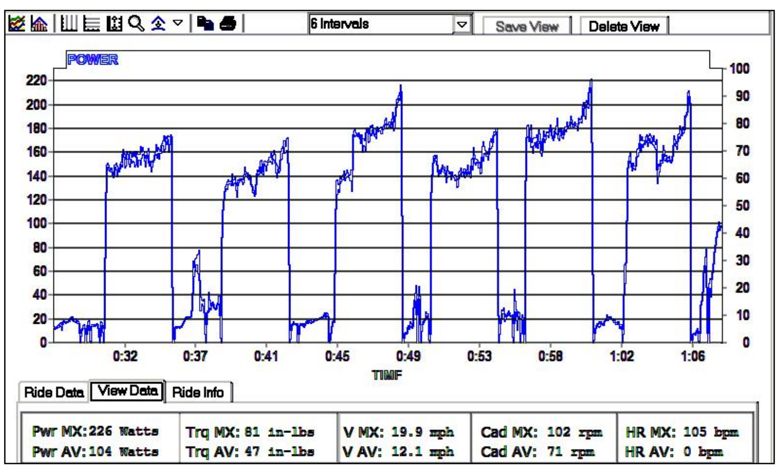


Figure 47. Suboptimal intervals. Dips in power in the middle of fourth and sixth interval as the athlete loses focus. Surges at the end of intervals 3, 4, 5, and 6. See the discussion in the text.

Heart Rate

Suggested end-of-interval heart rates for six 3- to 5-minute intervals are 80%, 83%, 86%, 89%, 90^{+}%, and 90^{+}% of maximum.

Fresh athletes may be able to work at heart-rate intensities higher than these values.

Tired athletes may be able to achieve target power outputs, but heart-rate percentages may be lower due to heart-rate power decoupling as discussed on page 143.

In the less effective and more effective intervals shown in Figure 46, notice that the end-of-interval heart rates of the less effective intervals are 78%, 78%, 81%, 84%, 87%, and 92% of maximum heart rate.

The end-of-interval heart rates of the more effective intervals are 79%, 80%, 85%, 89%, 93%, and 96% of maximum heart rate—close to the suggested values.

Gearing

Heavy gearing and slow rpm (50 rpm) emphasize muscular fitness. Light gearing and very fast rpm (150) emphasize neuromuscular fitness. If these fitness elements are limiters, neither one of these approaches may allow maximum oxygen uptake fitness to be overloaded.

For most riders, a cadence between 80 and 110 will prove best in developing maximum ramped power and oxygen uptake.[49] Mountain bikers and time trialists may prefer the lower range, pursuiters and criterium riders the upper range.

In general, when you are able to finish 3- to 5-minute intervals in the 100 to 110 rpm range, shift to a harder gear next time.

[49] Mora-Rodriguez R, Aguado-Jimenz R (2006). *Performance at high Pedaling Cadences in Well-Trained Cyclists.* Medicine and Science in Sports and Exercise, 38, 953-957.

Position

In general, start with a lower position. Work your way to a higher position. For example, progress from handlebar drops, to aerobars, to brake hoods, and to handlebar tops.

As your hip angle opens up, it will be easier to produce more power.

This approach also is valuable because slightly different muscle groups are worked.

Changing position each minute also helps riders psychologically break down the interval into more manageable chunks.

Focus

As described in more detail on page 107, when working at hard steady state, it is helpful to maintain narrow, internal, and associated focus.

Specifically, it is helpful for many riders to concentrate on breathing, and time their breathing with pedal stroke.

Maximum oxygen uptake occurs at breathing rates about 60 times per minute. Near the end of 3- or 4-minute intervals, rates may be even higher.

When performing intervals at a cadence of about 90 rpm, this means breathing every stroke and one half.

The following approach helps most riders:

- Get into your breathing rhythm 5 to 10 seconds *before* you start working.
- Breathe every two strokes for the first minute or two.
- Breathe every stroke-and-one-half for the next minute or two.
- Finally, for the last minute, breathe every stroke of the left leg for a count of 6 to 10, alternate and miss half a stroke, then breathe every stroke of the right leg for a count of 6 to 10. Then switch again, and again, and so on.

Workout Guidelines

Pyramid Intervals

Since a variety of training intervals is a good idea, many coaches suggest and many athletes perform pyramid intervals.

For example, an athlete might perform seven intervals in this sequence: 1-minute, 3-minute- 5-minute, 10-minute, 5-minute, 3-minute, and 1-minute.

Although such a variety may be useful, I rarely prescribe such protocols.

I find it psychologically and physiologically easier to work on one length of interval at a time. In some of the weeks of the Rapid HIT workouts outlined later in this book, for example, I prescribe six 4-minute intervals and twelve 30-second intervals one day and three 10-minute intervals another day.

Workout Guidelines

9-Minute Progressive Intervals

Beginning athletes often have difficulty knowing how to pace the 3- to 5-minute intervals described above on page 115.

The progressive 9-minute intervals are a training trick to help teach you how to perform 3- to 5-minute intervals. They help you determine the gearing and cadence to use to achieve an effort you can sustain for 3 to 5 minutes.

Such longer cruise intervals, 6 to 12 minutes in duration, are in some ways easier than 3- to 5-minute intervals because the initial effort is less intense.

The last several minutes of such longer efforts may mimic the intensities of 3- to 5-minute intervals. Many athletes find it easier to “get into a workout” this way.

Six- to 12-minute efforts may also provide variety, be appropriate for road racing simulation, and for 10-mile to 40-kilometer time trial training.

Standard Protocol

On level ground, steady grade, or stationary trainer: Choose a moderate gear.

Pedal at a cadence of 90 to 100 rpm. Ride for 3 minutes. Increase the gear one cog harder. Keep the same cadence. Ride for 3 more minutes. Shift one cog harder once more. Ride for 3 more minutes, same cadence.

If your gears skip a cog, e.g. 17 to 15, then reduce by 5 rpm when you shift.

Start each 3-minute segment in the handlebar drops. After one minute, move hands to the brake hoods. After another minute, move hands to the handlebar tops.

Heart rate: Aim for about 75% of maximum heart rate halfway (4.5 minutes) into the 9-minute interval. Aim to finish the 9-minute interval at 80% to 85%.

As you adapt and learn the exercise, you will be able to sustain higher heart rates, aiming for 85% of maximum heart rate midway into the interval, and finishing the 9 minutes at 90% to 95% of maximum heart rate.

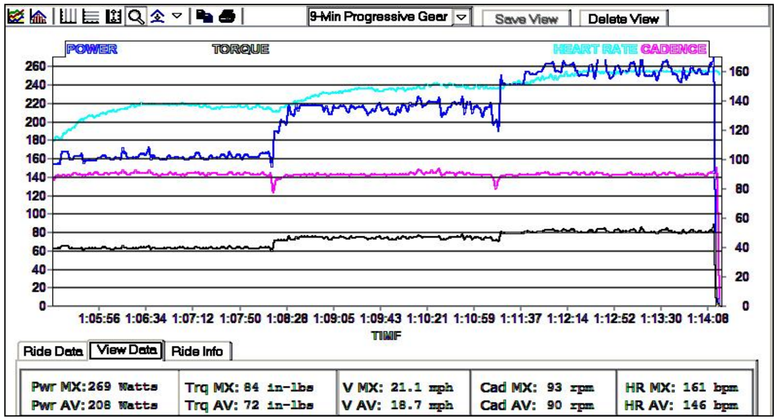


Figure 48. 9-minute progressive interval. PowerTap download. Power, blue; heart rate, turquoise; cadence, pink; and torque, black.

Standard protocol: Increasing gear every three minutes, cadence constant at 90 rpm.

Variations

1. Keep gear constant, increase cadence 5 to 10 rpm twice: once at the end of 3 minutes and once again at the end of 6 minutes.
2. Increase cadence 2 to 5 rpm each minute for 3 minutes.

   At the end of 3 minutes, increase the gear by one cog and return to your starting cadence. Again, increase cadence 2 to 5 rpm each minute for 3 minutes.

At the end of another 3 minutes, 6 minutes into the interval, once again increase the gear by one cog and once again return to your starting cadence. Again, increase cadence 2 to 5 rpm each minute for 3 minutes.

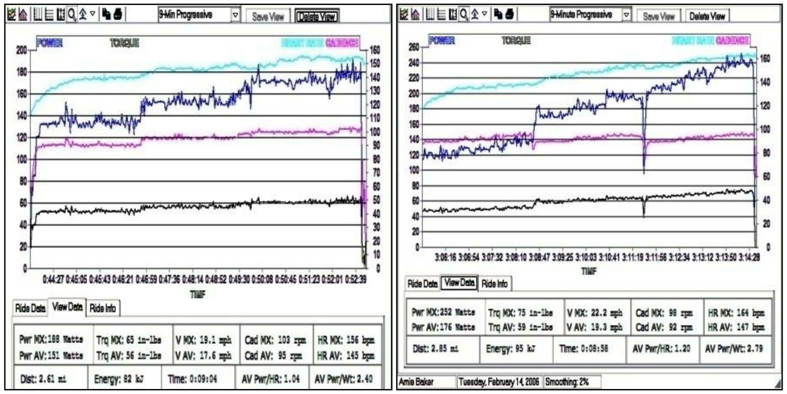


Figure 49. Different approaches to 9-minute progressive intervals. PowerTap downloads. Power, blue; heart rate, turquoise; cadence, pink; and torque, black.

Left: Variation 1. Gear constant, increasing cadence 5 rpm every three minutes.

Right: Variation 2. Increasing gear and cadence. Cadence increases from 90 to 95 during each 3-minute segment. Gear increases twice—at the end of 3 minutes and at the end of 6 minutes.

Workout Guidelines

Stand and Surge

This exercise has two parts: (1) a steady stand and (2) 15-second surges at the top of each minute.

Stand-Climbing Tempo

On the road, stand climbing is important for accelerations and crotch and muscle relief.

Most riders benefit from climbing in and out of the saddle. However, the majority of riders spend most of their riding time seated. Stand climbing tempo training helps make up for this deficit.

Although not performed at high intensity, stand-climbing tempo helps prepare riders for high-intensity standing surges, adds variety to workouts, and improves general aerobic and muscular endurance.

On a stationary trainer, perform standing and other exercises to stimulate climbing muscles with the front of a stationary trainer elevated 6 to 8 inches higher than the rear. For information about how to safely raise the front of your trainer, see *Make the Trainer Stable* on page 135.

Generally, use a big gear.

- Cadence 50 rpm to 60 rpm.
- Heart rate about 75% of maximum near the end of the stand.
- Power at 2 to 4 watts per kilogram.

Chunk workouts into pieces to make it easier to focus. For example, you might chunk standing for 15 minutes into 5-minute sections: 2 minutes on the brake hoods, 1 minute on the handlebar tops, 1 minute in the handlebar drops, and 1 minute leaning on handlebars.

Beginners should sit for 30 seconds every 3 to 5 minutes.

Standing Surges

Stand as above.

If surges to more than 20 rpm faster are easier, your resistance device may be maxed-out. Read more about this on page 132.

Surge 15 to 20 rpm faster for 15 seconds at the top of the minute.

Keep standing for the 45 seconds at a cadence 50 rpm to 60 rpm until the next surge.

Generally aim to perform each surge at a higher intensity.

- Heart rate will rise to 85^{+}% of maximum at the end of the last surge.
- Surges will be at 4 to 8 watts per kilogram depending upon fitness level.

Approaches

1. Fit athletes may aim for a higher stand-climbing tempo—for example, 80^{+}% of maximum heart rate.
2. Aim for increased power in surges and reduce baseline-standing power.
3. Aim for steady surge power throughout surges, not increasing power each surge.

It is not that one method is preferable.

With a higher baseline power the overall workload will be a little higher, and the overall aerobic demand (heart rate) higher.

With a lower baseline power, the surge efforts will be performed at a higher intensity.

With an increasing power for each surge, quality and motivation are likely to remain higher than blasting surges from the beginning.

Simplistically one might say that the higher baseline power approach is closer to the training demands of a triathlon or time trial; that the higher surge approach is closer to the training demands of a criterium road race or cross-country mountain bike event.

Varying your approach to the stand and surge is probably best.

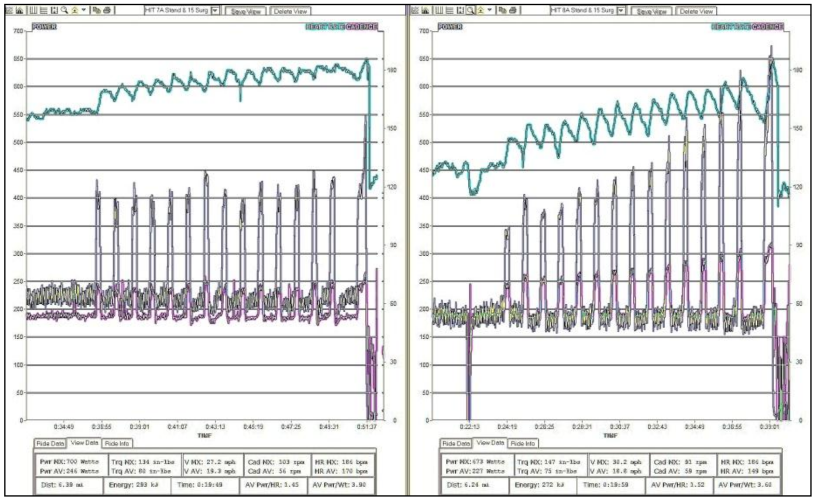


Figure 50. Varying approaches to stand and surge. Heart rate, green; power, black; and cadence, red.

Left: Steady baseline power, steady surges.

Right: lower baseline power, especially between surges, increasing power during surges.

Overall

The continuous standing requires at least mid-level aerobic work. It is easy to float seated exercises. When standing, if power output is low, you will plop down on your saddle.

The surges get you to threshold or beyond.

Sprints

Sprints Defined

Sprints as outlined in this book are intervals of 30 seconds duration or shorter.

Adapt

Learn and adapt to exercises before performing them "all out."

Although in some ways you may already be able to work at higher intensities, in other ways you may not be. For example, you may be physically able to perform high-rpm intervals, but until you adapt, excessive soreness after high-rpm intervals is likely.

Pacing

As with most intervals, a pacing strategy often works best. Efforts longer than 10 seconds require a pacing strategy. Efforts of 10 seconds or shorter may not.

Cadence

The training objective of the interval determines the suggested cadence range.

Power

To develop maximum power, select a moderate gear that allows a cadence between 120 and 140 rpm. A 53/17 or a 39/13 is a typical gear choice.[50]

[50] Gardner AS, Martin DT, et al (2005). *200m Competition Power-Pedaling Rate Relationship In World Class Male And Female Track Sprint Cyclists.* Medicine and Science in Sports and Exercise, 37 (5):453.

Strength

To develop maximum strength, or torque, select a moderately-heavy gear that allows a cadence between 100 and 120 rpm. A 53/15 is a typical gear choice.

RPM

To develop maximum rpm, select an easy gear that allows a cadence higher than the current maximum. A 39/27 is a typical gear choice.

30-Second Sprint Intervals

Pace within each interval and from interval to interval to perform near the maximum work possible for the total number of intervals prescribed.

Perform most of these intervals with hands in the drops and start out of the saddle.

Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.

Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.

Start from a cadence between 80 and 100 rpm.

To develop power, select a gear that allows a cadence between 120 and 140 rpm. To develop strength, or torque, select a gear that allows a cadence between 100 and 120 rpm.

Power at 3 to 10 watts per kilogram.

Crank torque at 1.5 to 5 pound-inches per kilogram.

15-Second Sprint Intervals

Perform these intervals almost "all-out" from the beginning of the intervals.

Perform most of these intervals with hands in the drops and start out of the saddle.

Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.

Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.

Although effort is anaerobic, do not expect anaerobic-level heart rates. (For more information about this, see page 38.)

Start from a cadence between 80 and 100 rpm.

To develop power, select a gear that allows a cadence between 120 and 140 rpm. To develop strength, or torque, select a gear that allows a cadence between 100 and 120 rpm.

Power at 4 to 12 watts per kilogram.

Crank torque at 3 to 8 pound-inches per kilogram.

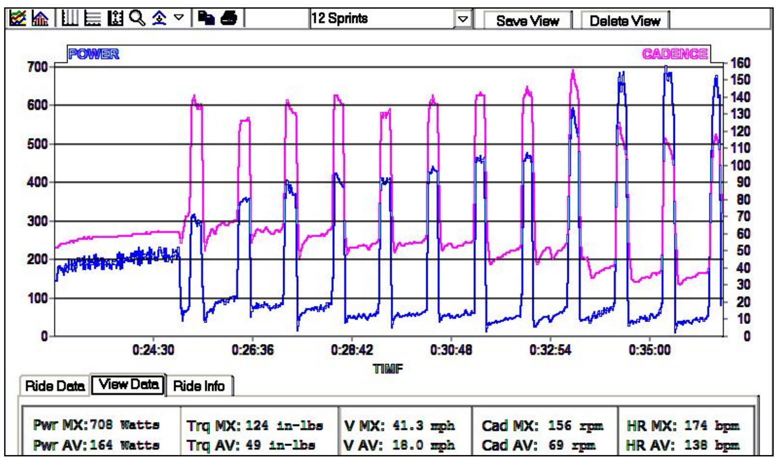


Figure 51. Twelve 15-second sprints. Power, blue; cadence, pink.

In this first sprint-interval session, the athlete paces and holds back for the first eight intervals.

With a cadence over 140 and relatively modest power output after the first sprint, the athlete shifts to a harder gear. With cadence over 150, the athlete shifts again after the ninth sprint.

5-Second Sprint Intervals

Perform these intervals “all-out” from the beginning of the intervals. As soon as your cadence drops, stop.

Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.

Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.

Although effort is anaerobic, do not expect anaerobic-level heart rates. (For more information about this, see page 38.)

Start from a cadence between 80 and 100 rpm.

To develop power, select a gear that allows a cadence between 120 and 140 rpm. To develop strength, or torque, select a gear that allows a cadence between 100 and 120 rpm.

Power at 5 to 15 watts per kilogram.

Crank torque at 5 to 13 pound-inches per kilogram.

Leg Speed Drills

Leg Speed Defined

Leg speed is fitness related to how fast you can turn the cranks; your fastest or sustainable cadence.

As discussed in *Fitness Elements*, on page 16, leg speed is a neuromuscular fitness.

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, often over 200 rpm.

Leg-Speed Exercises

Spin-Ups

These exercises are used as warm-ups for almost every stationary trainer session.

Generally, use your easiest gear so that your ability to perform these exercises is not limited by heart rate or leg strength. Gear and resistance should be very low.

Start at about 60 rpm—that is pedaling one stroke every second. Build up 5 rpm every minute until you are spinning about 120 rpm.

Then, starting again at 60 rpm, build up 5 rpm every 30 seconds until you are spinning 130 rpm to 140 rpm.

Finally, starting again at 60 rpm, build up 5 rpm every 15 seconds until you are spinning 150 rpm to 160 rpm.

By trying to spin to a little higher rpm every few sessions, you will probably find that your leg speed increases.

Sprints

The easier the gear, the shorter the effort, and the faster the cadence, the more leg speed will improve.

ILTs

As discussed on page 111, isolated-leg (one-leg) training with low resistance at about 80 rpm improves neuromuscular fitness and leg speed to develop the ability to ride at much faster cadence.

Spin Wars

An occasional progressive exercise, similar to spin-ups, increasing cadence 5 rpm every 10 seconds to maximum.

A fun, generally self or group semi-competitive exercise.

Caution: Attempt only when you have adapted to spin-ups. Generally, use your easiest gear so that your ability to perform these exercises is not limited by heart rate or leg strength. Gear and resistance on your trainer should be low.

Spins

These exercises are often the last exercise of a stationary trainer session.

Unless overly fatigued from the trainer session, it is often easier to hold a fast spin at the end of the session than at the beginning.

As a modest guideline, riders are encouraged to spin at about 100 rpm for 5 minutes with low resistance.

As riders improve, many riders are able to sustain more than 130 rpm for 10 minutes.

The Gear-Cadence Product

One element of bicycling workouts not available in most other sports is the ability to change gears. A runner cannot change to different length legs, and a basketball player does not use differently weighted or sized balls in practice. However, cyclists can and do change gears, and this changes the interplay of fitness elements.

For example, a 3-minute interval at a heart rate of 150 performed at a cadence of 150 in an easy gear is quite different from a 3-minute interval performed at a heart rate of 150 at a cadence of 50 in a hard gear.

Remember, at slower cadences muscular fitness is selectively trained. At faster cadences, aerobic fitness is selectively trained.

Performing a 3-minute interval at 100 to 110 rpm is more specific to the demands of track pursuiting or criterium windups. Performing a 3-minute interval at 60 to 80 rpm is more specific to the demands of hill climbing. Performing a 3-minute interval at 80 to 100 rpm is suitable for general road riding.

By experience, by trial and error, you will find out just how hard you can work for, say, 3 minutes in a 39/14 as compared with a 53/16. If you have a table of the gears and cadences, you will be able to qualitatively compare workloads quickly, the learning curve about workloads will be steeper, and you will be more productive in dialing in your efforts.

Table 25 below shows relative gear-cadence loads in different gears and cadences. The table was made by dividing the number of cog teeth into the number of chainring teeth and multiplying by cadence.

For example, the gear-cadence load in a 53/16 from 80 to 90 rpm is quite similar to the loads in a 53/14 from 70 to 80 rpm, a 39/14 from 95 to 110 rpm, or a 39/16 from 110 to 125 rpm.

This represents a gear-cadence load typically used by experienced recreational riders or beginning racers during 3 to 4 minute intervals. (Your gearing may be different. Read why in *Gearing* on page 134.)

Gear-cadence load is a measure of relative speed. It is a measure of qualitative workload, but not absolute quantitative workload.

Some trainers are designed to increase workload as the cube of speed (which is the real-world effect of air resistance). In trainers so designed, a 10% increase in gear-cadence load represents a 33% increase in workload. A 25% increase in gear-cadence load may present a 100% increase in workload. (Math buffs: $1.25^3 = 2.0$.)

Poor trainers max out—an increase in rear-wheel speed sometimes does not represent any increase in load at all.

Climbing surges are performed at a gear-cadence product that is about 25% greater than the 3-minute gear-cadence product, and represent about a doubling of power. This is represented by the gray bar in Table 25 below.

RPM	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
39-11	177	195	213	230	248	266	284	301	319	337	355	372	390	408	425	443	461	479	496	514	532
12	163	179	195	211	228	244	260	276	293	309	325	341	358	374	390	406	423	439	455	471	488
13	150	165	180	195	210	225	240	255	270	285	300	315	330	345	360	375	390	405	420	435	450
14	139	153	167	181	195	209	223	237	251	265	279	293	306	320	334	348	362	376	390	404	418
15	130	143	156	169	182	195	208	221	234	247	260	273	286	299	312	325	338	351	364	377	390
16	122	134	146	158	171	183	195	207	219	232	244	256	268	280	293	305	317	329	341	353	366
20	98	107	117	127	137	146	156	166	176	185	195	205	215	224	234	244	254	263	273	283	293
30	65	72	78	85	91	98	104	111	117	124	130	137	143	150	156	163	169	176	182	189	195

RPM	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130	135	140	145	150
53-11	241	265	289	313	337	361	385	410	434	458	482	506	530	554	578	602	626	650	675	699	723
12	221	243	265	287	309	331	353	375	398	420	442	464	486	508	530	552	574	596	618	640	663
13	204	224	245	265	285	306	326	347	367	387	408	428	448	469	489	510	530	550	571	591	612
14	189	208	227	246	265	284	303	322	341	360	379	398	416	435	454	473	492	511	530	549	568
15	177	194	212	230	247	265	283	300	318	336	353	371	389	406	424	442	459	477	495	512	530
16	166	182	199	215	232	248	265	282	298	315	331	348	364	381	398	414	431	447	464	480	497
20	133	146	159	172	186	199	212	225	239	252	265	278	292	305	318	331	345	358	371	384	398
30	88	97	106	115	124	133	141	150	159	168	177	186	194	203	212	221	230	239	247	256	265

3-4 Minute Interval Range **Black bars represent selected examples of similar workloads typical of 3-4 minute intervals.**

15-20 Second Surge Range **The gray bar represents a higher workload that corresponds to a range for climbing surges.**

Table 25. Gear-cadence products.

Stationary Training

Stationary training is riding a bicycle in place. It may be on a Lifecycle or Spinner machine in a gym, or it may be on your own bicycle mounted on a special support.

Some benefits of stationary trainers are difficult to obtain in any other way. There is value in trainer workouts all year round.

Introduction

Many people think of riding stationary trainers when the weather is cold or rainy, or when they are on vacation, to keep cycling fitness, in their hotel gym.

For most people, riding a trainer is a solitary experience, but it need not be that way. Consider forming a stationary trainer group and training together.

Trainers allow faster riders to ride with slower ones. It allows team members to bond. No one is left behind!

Stationary Trainer Advantages

- Fun.
- Time efficient.
- Convenient.
- Relatively inexpensive.
- Good in bad weather or in the dark.
- Promotes fitness.
- Bicycling-specific.
- Ideal for intervals.
- Precise, controlled intensity.
- Allows maximum workouts.
- Many trainer exercises are psychological lessons as much as physical exercises.
- Teaches focus.
- Safe. Accidents are rare.
- Motivating and confidence building.
- Social. Riders of all levels can train together.

What Type of Trainer Should I Buy?

Use a Conventional Stationary Trainer

If possible, get an old-style conventional trainer, one on which you mount your bike after taking off the front wheel, or a "track-stand" type trainer, one on which your rear wheel is cradled and your front wheel is left on.

Because they are so stable, front-and-rear-mounted trainers allow workouts that are more effective. However, they are less portable than track-stand trainers are.

Figure 52. Stationary trainer setup. Trainer with attachment at front and rear dropouts provides unmatched stability. Use of fan, wood block with cutouts, outboard leg posts, and computer monitoring is described in the text.

Figure 53. CycleOps brand track-stand type wind trainer.

Rollers have limited intensity-training applications. Changing speed or cadence on rollers does not change torque. For more information about torque and rollers, see page 56.

Lifecycle or Spinner machines may be great to use when on vacation. However, they do not mimic the "feel" of road and air resistance as closely as the much less expensive conventional trainers, which allow you to use your own bicycle.

When you use your own bicycle—with correct bike fit, the pedals you are used to, and the seat to which you are accustomed—you get a better workout.

Resistance: Fan, Magnet, Fluid, Electronic

You will need a resistance device: fan (wind), fluid, magnetic, or electronic.

Unit Type: Introduction

Fan-resistance trainers are generally best, although fewer of these units are being manufactured.

"Road feel" results from a combination of the trainer's power curve and inertia. Power curve and inertia are discussed in more detail below.

Fan-resistance trainers provide the best road feel and are the least expensive devices. They are less likely than magnetic- or fluid-resistance devices to max-out. Fan-resistance trainers are noisier than other options; noise level varies and may be considerable.

Magnetic-resistance trainers perform imperfectly. The "magnet" often feels lumpy. As effort and cadence increase, the magnetic resistance increases linearly or does not vary, so you do not get the right road feel. Many units have had a history of failure.

Fluid-resistance trainers have a better road feel than magnetic ones do. Higher-end models max-out at high power outputs. Many units have had a history of failure due to leaking.

Technology is developing. Several brands of electronic trainers provide power (watts) output, along with an interactive computer-generated video display. Preprogrammed and programmable courses, as well as other features motivate some riders. These trainers can be valuable tools.

Electronic trainers still do not have as good road feel as a conventional fan-resistance trainers. Many have a lumpy feeling, especially at low cadences. Some electronic trainers are fixed-gear units that are unsuitable for training some fitness elements.

While the power-measuring feature of electronic trainers is generally reliable (repeatable), it is not always valid (accurate). Using an accurate power-measuring device (see page 39) on a standard bicycle on a fan or fluid trainer may be preferred.

Power Curve

On level ground, aerodynamic resistance, rolling resistance, mechanical friction, and other factors create power demands. Aerodynamic power requirements rise as the cube of speed (or cadence, if gear is constant). Other power requirements remain fixed or rise as lower exponents.

If power requirements results just from aerodynamic resistance, increasing flat-land speed 20% from 20 to 24 miles an hour requires 70% more power ($1.2^3 = 1.7$).

If power demands are increasing as the cube of speed or cadence, then when cadence increases from 60 rpm to 80 rpm (increases to 133% of baseline) power demands slightly more than double ($1.3^3 = 2.2$ or 220% of baseline).

When climbing, power requirements rise in direct proportion to speed.

The best stationary trainers mimic road feel by power resistance curves rising between the square and cube of speed. Said differently, for speed to double, power requirements go up about six-fold.

Trainers that come close to matching this power curve have better road feel.

Magnetic units often have adjustable resistance levels that you can dial in on the resistance unit or control remotely with a handlebar-mounted changer. Being able to adjust resistance is good.

Unfortunately, the power curve of resistance on magnetic trainers rarely results in good road feel. Increasing power demands result from increasing speed, not increasing torque. Magnetic trainer power curves are illustrated in Figure 55 and Figure 59.

Examples of stationary trainer power curves, including power curves with an adjustable magnetic resistance unit, are shown in Figure 54, Figure 55, and Figure 56.

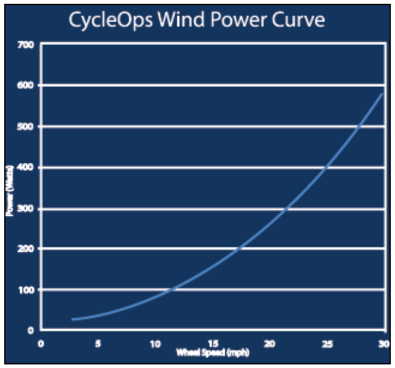


Figure 54. CycleOps fan (wind) trainer power curve.[51] This brand's least expensive trainer has good road feel. Power requirements rise roughly as the square of speed.

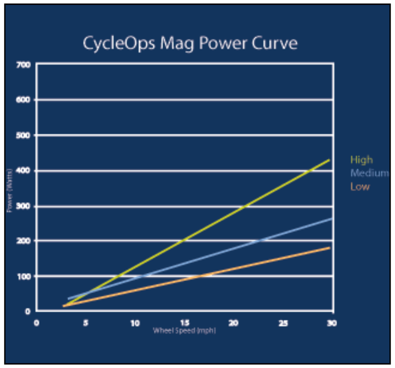


Figure 55. CycleOps magnetic trainer power curve. These typical linear power curves have poor road feel.

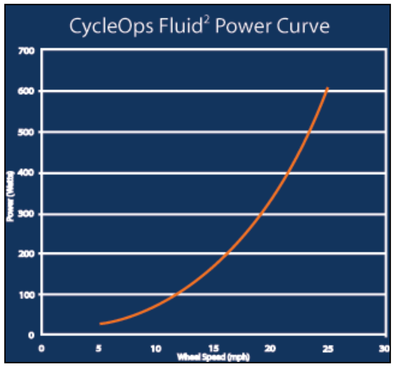


Figure 56. CycleOps fluid trainer power curve. This expensive trainer is quiet and has a good road feel—similar to the wind trainer in Figure 54.

Read more about power curves in the chapter on torque-based training beginning on page 53.

Resistance Varies

Not only is resistance different between different trainer models, even within the same model manufacturing variations or errors result in different resistances and power curves.

As Figure 57 demonstrates, at the same wheel speed, two different units may differ considerably in resistance. In this case, two different CycleOps2 fluid trainers were tested on a bicycle equipped with a PowerTap wattmeter. The bicycle was ridden in a 55/14 gear at about 55 rpm or about 25 kilometers (16 miles) per hour.

Trainer roller pressure was controlled and the same on both trainers.

Riding the first trainer resulted in a power demand of 180 watts. The second resulted in a power demand of 120 watts.

According to the manufacturer-supplied power curve, Figure 56, at 16 miles per hour the power demand should be about 180 watts. The first unit performed as expected, the second unit did not.

Without a frame of reference, it is often difficult for an individual to know how their trainer is performing.

[51] From http://cycleops.com/ 2-25-2004. Actual power curve depends upon tire pressure, tire type, and trainer resistance unit roller pressure on the tire.

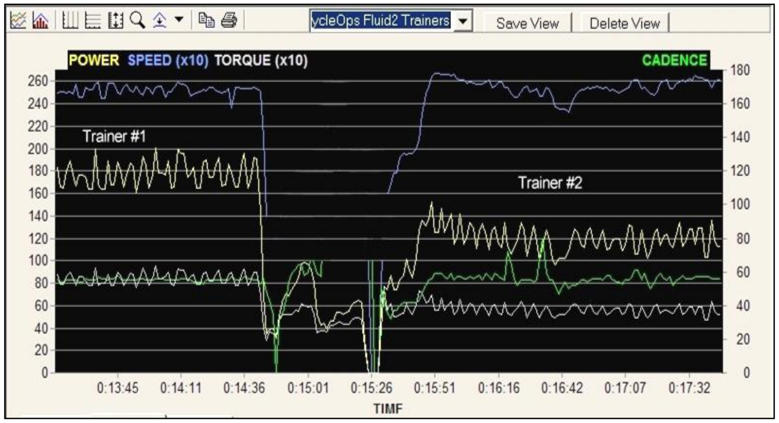


Figure 57. Two trainers, different resistances. Curves from the top: Speed, blue; power, pale yellow; cadence, green; and torque, white.

Two different units of the same PowerTap Fluid2 model trainer. The first unit created a demand of about 180 watts. At the same wheel speed, the second unit created a demand of 120 watts.

Checking Your Trainer Power Curve

If you have a power meter, you can check your stationary trainer's power curve.

Figure 58 illustrates how when cadence rises 16% from 56 to 65 rpm, power rises 50% from 200 to 300 watts. This is similar to what happens on level ground: power changing between the square and the cube of speed.[52]

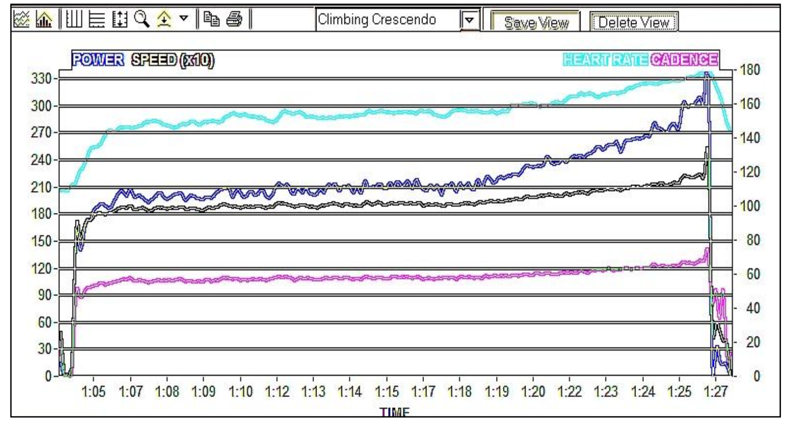


Figure 58. Changing resistance curve. Twenty minutes of standing on a stationary trainer. Cadence is fairly constant for the first 10 minutes at 56 rpm. In the last 7 minutes, cadence rises 1 rpm per minute. As cadence rises from 56 to 65 rpm, power requirements rise from 200 to 300 watts.

Inertia

When road riding on level ground, if you ease up on the pedals, inertia keeps you going—you slow down relatively slowly. When riding uphill, if you ease up on the pedals, you immediately slow down relatively quickly.

Trainers that match the inertial effect of riding on level ground have better road feel. Fan-resistance trainers do this intrinsically by design. Other resistance devices improve this characteristic with the use of flywheels—in general, the more massive the flywheel the better.

Maxing-Out

When a unit maxes-out, increasing speed or cadence does not meet increasing resistance. Powerful riders are commonly able to max out inexpensive units.

[52] The square of a 16% increase in speed would be 1.16 X 1.16 = 1.34, or a 34% increase. The cube of a 16% increase in speed = 1.56 of a 56% increase.

Many units, regardless of type, fall into this category. Electronic trainers generally do not have this problem.

Stationary trainer max-out is illustrated in Figure 59.

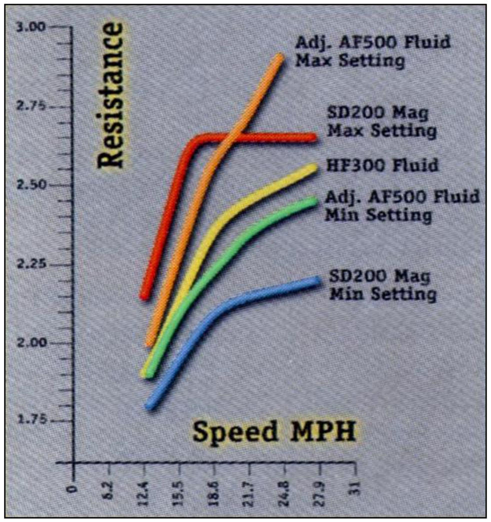


Figure 59. Max-out. Poor road feel. Performance-brand fluid and magnetic trainers. Note how the SD200 magnetic unit maxes out at about 16 mph. None of these curves follows a cube function. None of these trainers has good road feel.

Not Enough Resistance?

Similar to, but not the same as maxing-out. When a trainer maxes out, increasing speed or cadence does not meet increasing resistance.

With small-fan trainers, increasing speed or cadence will meet increasing resistance, but you may be already in your biggest gear at as high rpm as you can comfortably pedal.

There are several options:

- Increase trainer roller pressure, generally by turning a knob clockwise.
- Use a smaller cog, e.g. a 12 or an 11.
- Use a larger chainring e.g. a 55.
- Get a trainer with more resistance.

Resistance Unit Type Summary

Fan-resistance units are generally the best. Fluid units provide better road feel than magnetic units. Expensive electronic units may provide ancillary desired features.

	Fan	Fluid	Magnetic	Electronic
Cost	+	++	++	++++
Quiet	+	+++	+++	+++
No Max-Out*	++	+	+	++++
Road Feel	++++	+++	+	++
Reliability	+++	+	+	++

Table 26. Trainer resistance summary. + is least. ++++ is most. Desirable qualities are highlighted in green. *Max-out depends upon specific brand.

Other Factors to Consider in Purchase

Portability

- Does the trainer lie flat when folded?
- How heavy is the trainer?

Bicycle Attachment

- Does the rear-axle support accept and securely fasten modern, non-circular skewers?

Stability and Leveling

- Does the trainer have stability or leveling screws to improve stability on uneven surfaces?

Stationary Trainer Hints

Use an Old Bike

Without the bike moving freely underneath you, enormous pressures are generated on the bicycle.

The bike you use on the trainer gets wet with sweat and rusts or otherwise corrodes in time. The headset, with the bike always “going” straight ahead, becomes grooved. For these and many other good reasons, if you are a regular stationary trainer enthusiast, do not use an expensive bike.

An old or used bike will do, just make sure the position set up is the same as your regular bike.

Gearing

Although almost any gear setup can be made to work, the type of cog setup that has worked best for most riders is a 12-13-14-15-16-17-20-24-27.

The closely spaced high gears allow you to tune the hard efforts precisely. The large 27-cog allows you to work on spin and leg speed without muscle strength or aerobic capacity limiting the drill.

Figure 60. Gearing. This old 7-speed has closely spaced 12-13-14-15-16-17 cogs for precisely tuning most exercises; a 27-cog for high-cadence exercises.

The resistance device affects the power necessary to turn the cranks. For example, in some 53/16 set-ups, 200 watts of power might result in 90 rpm; in others just 60 rpm. Gearing suggestions are general indications of where you might be.

Monitors: Cadence, Heart-Rate / Power

Specific workout plans demand a cadence computer, which allows you to tune your efforts precisely, see your progress, and record your improvement.

A heart rate monitor and a power meter are also valuable. They give important feedback about aerobic and muscular work.

Figure 61. Computer monitors mounted on a piece of PVC pipe. Redundancies provide reliability for workouts, leading stationary trainer classes, and comparing or evaluating other new products. From the left: Performance-brand main timer and hard-wired cadence and speed computer. Polar-brand heart-rate monitor with wireless cadence. PowerTap power-monitor with virtual cadence and speed. Timex split-time timer.

Control Trainer Settings

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.

Keep Records

Record your workouts. Keeping track allows you follow your progress and plan subsequent workouts. It is motivating and instills confidence.

Raise the Front of the Bicycle/Trainer

Trainers raise the back of the bicycle up to two inches. Raising the front more than this eases pressure on the crotch and makes workouts more comfortable.

Raising the front of the bicycle/trainer will also help you to train hill-climbing muscles.

Most riders should keep the front of their bicycle/trainer elevated for all workouts. Exceptions include riders preparing specifically for time trials or downhill mountain bike events.

Read more about how to raise your bicycle/trainer and hill-climbing workouts in the demo stationary trainer workout on page 136.

For examples of safely raised bicycles/trainers, see Figure 52 on page 129 and Figure 62 on page 137.

Make the Trainer Stable

Without fail, someone has fallen off their trainer every year at our annual stationary trainer classes.

Make sure the bicycle is securely attached to the trainer.

If your rear wheel has a skewer that does not fit perfectly securely in the trainer supports, replace it with one that does.

Trainer workouts are improved when the front of the trainer is stabilized. A front-fork mounted trainer, as in Figure 52 is best. Other good alternatives include a fork-mounted support on a stepladder, as in Figure 62 on page 137, or mounting the front wheel on a second trainer.

Raising the front of the trainer to simulate climbing? Front wheels on telephone books do not work. Small coolers or tool cases are unstable. Plain wood is marginal. Cutouts on blocks of wood or molded plastic are better. See Figure 62 on page 137.

Reader Warren Carswell writes: “During the past Vuelta A España I propped my front wheel on the TV to simulate a couple of the climbs. It worked fine until I stood and cracked the TV.”

Fluids and Calories

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

Drink at least 16 ounces of fluids (one standard waterbottle) per hour of exercise.

Aim for 300 calories per hour of exercise. Carbohydrate gels or carbs-in-solution—primarily maltodextrins or glucose polymers—work better than solid foods during high-intensity workouts.

Fans for Cooling

Fans help evaporate perspiration and help to prevent sweat dripping on your equipment. You will be able to work harder and longer with a fan.

Group Rules

Stationary training groups are fun and improve the quality of training sessions for many riders.

Although a chance for team-bonding or socializing, keep sessions effective by following a few simple courtesies:

- Respect everyone’s time:
    - Start on time.
    - Keep on time.
    - Finish on time.
- Make it a rule not to talk during exercises when cadence is over 100 rpm, heart rate is greater than 75% of maximum, or power is greater than 80% of time trial pace.
- Avoid grunting.
- Turn off mobile phones.
- Pick up after yourself—gum, wrappers, and other trash.

Demo Stationary Trainer Workout

Workout Plan

The secret of falling in love with stationary training is to have a plan, a goal.

Many people find it hard to ride trainers for more than 20 to 30 minutes. Those bored with stationary training usually ride at the same speed and in the same gear for all of their workouts. Challenging variation is required.

Here is a typical workout. Between each exercise is an easy-pedaling rest period.

Overview

Duration	Exercise	Gear	RPM	Intervals
10 min	Warm-up	39/27	To 120	
20 min	Isolated leg	53/18	50–60	4 & 3 min reps
10 min	Climbing	53/14	50–60	
25 min	Progressive	53/16	90	2 x 9-min reps
20 min	30" intervals	53/16	100^{+}	6 x 30-sec reps
10 min	Cool-down	39/27	100	

Workout Basics

Different aspects of these fitness parts are emphasized during different parts of the workout.

Gears and cadences are meant to be examples only. Rider fitness, types of trainer, and trainer setup all affect power output and make predetermined gear-selection impossible.

As with any new exercise, do not start out performing the exercises all-out or doing extra-long sessions.

Warm-up, Spin-up

The first 10 minutes are spent warming up. Choose the easiest, or almost easiest gear, available.

Start at about 60 rpm—that is pedaling one stroke every second. Build up 5 rpm every minute until you are spinning about 120 rpm. If you are new to cycling, it may take some time to be able to spin this quickly.

Isolated Leg Training (ILT)

One of the best ways to work on leg strength is one leg at a time.

By pedaling with just one leg—isolating that leg—you can focus on pulling up, on evenly applying force to the pedals around the stroke, and/or on building tremendous pushdown forces.

The key is to focus on the leg, not the cardiovascular system—which is precisely what ILT does.

You can rest your non-working leg on the back of the trainer, or use boxes or other objects to support it. Stabilizing the non-working leg makes ILT exercises easier and more effective.

An easy gear will force you to concentrate on smoothness and the pulling up motion of your leg. It will also help develop neuromuscular fitness, described on page 16.

Pedaling smoothly does not necessarily result in the highest average torque or power. Pedaling smoothly also means that you are not working your most powerful muscles to their potential.

A hard gear will, in addition, specifically strengthen your quads and glutes—the most important cycling propulsive muscles you have.

You may be able to perform high-power ILTs with so much force that you can push yourself up off the saddle. It helps to stabilize and anchor yourself with your arms. Pulling with your arms may allow you to work harder. If you are performing a left leg ILT, pull more with your left arm. Elite athletes may perform ILTs with such high torque that they may require two hands on same side of the handlebar to keep in the saddle.

ILTs are excellent exercises to help improve pacing. It is easy to mistakenly work too hard initially and not be able to maintain cadence for the prescribed duration.

Read more about torque-based training on page 53 and ILT training on page 111.

Hill Climbing

Live in Florida and need to train for a ride up hills or mountains? That is a challenge.

Merely increasing resistance does not do the job. The bicycle must be inclined.

Stationary training with the front of your bicycle/trainer elevated works to help train climbing muscles.

As stated earlier, this position is also more comfortable. Most riders should always keep the front of their bicycle/trainer elevated.

You can use a block of wood, proprietary trainer block, or other device. CycleOps-brand trainer climbing blocks are stackable.

Stability is important. See *Make the Trainer Stable* on page 135 and Figure 62.

As you gain experience, you can raise the front of the bicycle/trainer up to 8 inches. Since the trainer raises the back of the bicycle up to 2 inches, this amounts to a net front elevation of about 6 inches. Raising the bicycle/trainer more than this amount risks an accident, wheelieing backward.

Since percent grade equals rise over run, if the front of your bicycle/trainer is 6 inches higher than the rear, and the bike's wheel base is 40 inches, you have a roughly 15% grade.

If you raise the bicycle/trainer significantly, be initially cautious when performing sprints—check whether your knees may hit your handlebar.

Choose a hard gear. Stand up and pedal 50 to 60 rpm.

Build up to standing for 10 minutes. You will feel more confident and you will be stronger at getting over real hills when you meet them.

Trainer climbing volume is about half the maximum road-climbing rate. If you can climb 3,000 feet an hour up a long grade in one hour, give yourself 1,500 feet of climbing credit for every hour on an elevated stationary bicycle/trainer.

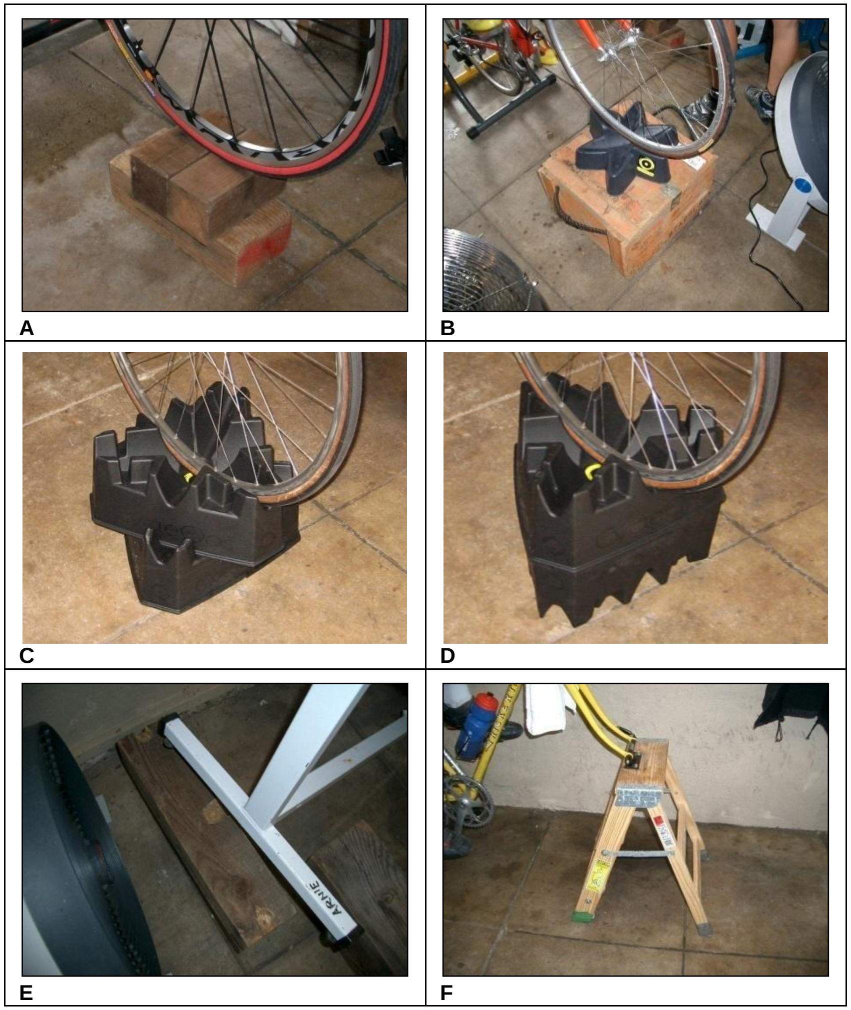


Figure 62. Raised bicycles/trainers. A, 4″x4″ blocks of wood--marginal; B, plastic trainer block on wood case--better; C, CycleOps climbing blocks stacked--good; D, CycleOps climbing blocks back-to back--good; E, 8″x4″ block of wood with cutouts for trainer leveling bolts--excellent; and F, 24″ stepladder with front-mount support—very good.

Progressive Intervals

Here is a favorite. Choose a moderate gear and pedal at 90 rpm for 3 minutes. Choose a gear that is hard enough so that at the end of these 3 minutes your heart rate is about 75 percent of your max, perhaps 140 to 150 beats per minute—too fast to carry on a conversation comfortably.

After 3 minutes, shift to the next harder gear and keep riding at the same cadence. At the end of these 3 minutes, you will be working very hard.

Then try one more 3-minute interval in yet another, harder gear. At the end of this 3-minute interval, you should be gasping and your legs should be heavy. Another minute or two of work, without recovery, should not be possible.

After 3 minutes of easy pedaling, repeat this 9-minute exercise.

Group Short Spin Intervals

Four people make this next exercise fun, although you can do it alone. For large groups, divide the group into four sections. With a class of 50, each section has about a dozen riders.

In turn each rider, or section, pedals as fast as possible in a moderately-hard gear, generally at 100 to 140 rpm for 30 seconds. Everyone else pedals easily. When the 30 seconds are up, the next rider or section takes over. The 30-second intervals progress through the riders until, after a rest of 90 seconds, it is up to the initial rider or section to start pedaling fast again.

Try for six 30-second intervals.

Cool-Down

A proper cool-down is almost as important as the warm-up. Spin your easy gear up to 100 rpm, hold for 4 or 5 minutes, and then gradually spin down. Remember the racehorse adage: By the time it gets back to the barn after a hard workout, it should be breathing normally and not sweating.

Give Yourself Credit: Log Your Workout

Keeping a training log is basic to documenting training, predicting performance, preventing overtraining, and effective coaching.

The training log (Excel file) bundled with this book provides a convenient way to record and track your workouts. It includes specialized worksheets partially pre-completed for the stationary trainer workouts found throughout this book.

Mileage

Mileage credit for each hour of stationary work is 10 to 20 miles. The lower part of the range is for beginning recreational riders; the upper part of the range is for racers.

Climbing

With the front of the trainer elevated, trainer climbing volume is about half your maximum road-climbing rate.

If you can climb at the steady-state rate of 3,000 feet an hour, give yourself 1,500 feet of climbing credit for every hour on a stationary trainer where the front of the trainer is elevated.

This often works out to be miles with two zeroes at the end. That is, if you figure you have ridden the equivalent of 15 miles with the front of the trainer elevated, give yourself credit for 1,500 feet of climbing.

Hours

An hour is an hour. It may be a hard hour, but it is an hour.

Work

If you use a power meter, you can log your work in kilojoules.

Intensity

Structured trainer workouts are generally hard.

Race Specificity

The following two heart-rate recordings show how well high-intensity training can specifically train you for the demands of racing.

Workout 7A Recording

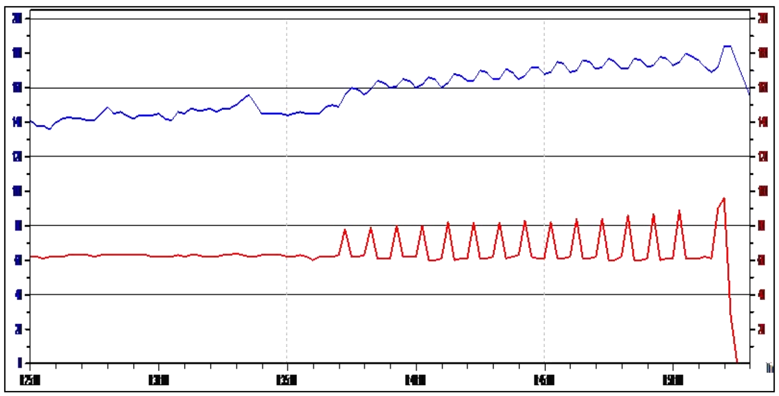


Figure 63. Standard HIT workout 7A. Stand climbing tempo and surges. Heart rate and cadence recording. The upper (blue) curve is heart rate. The lower (red) curve is cadence.

Stand Climbing Tempo and Surges

Here is a heart rate and cadence recording from the Standard 3-Month HIT workout outlined in more detail on page 159.

The recording shows the stand climbing tempo and surge sections.

The first 15 minutes of the stand are performed at a constant workload: in the same gear at 60 rpm.

Then, 15 surges are performed, increasing cadence about 20 rpm for 15 seconds for each surge.

Buckman Springs Road Race Recording

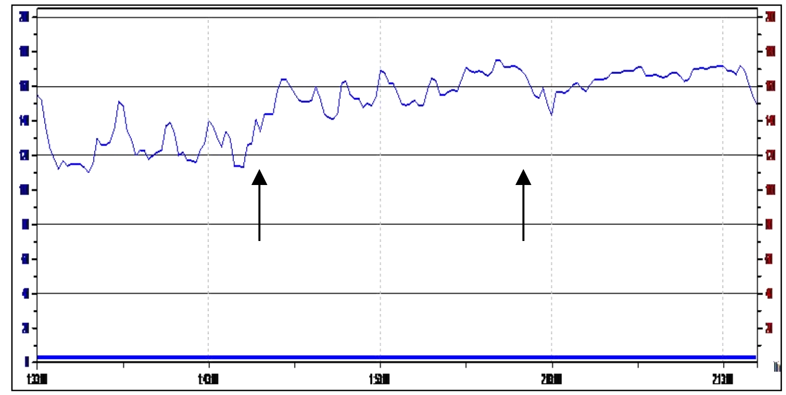


Figure 64. Buckman Springs Road Race. The climbing work parallels the 7A climbing tempo and surge workout. The first arrow marks the beginning of the climb. The second arrow is close to the summit.

The Course

This San Diego County road race is two 25-mile laps. Toward the end of each lap is a 4-mile climb that takes this rider about 15 minutes.

This heart rate recording is from the second lap. It is of the rollers leading up to the climb, the climb, and the final few miles to the finish line.

Heart rate is about 120 beats per minute in the pack on level ground, with increases to 150 beats per minute on rollers leading up to the climb.

Stand and Surge

About 1:45 into the race (first arrow) is the final major climb of the race. Similar to the surging in workout 7A, this rider surged repeatedly. After seven surges (second arrow), he was able to break clear and then time trial away for the win.

Role of Training

Maybe it will not be for the win, maybe it will be to stay with the group. Regardless, such climbing surges typify road racing and are crucial in road racing success.

Most athletes tire after a few such surges. If you can perform 15 surges in training, a half dozen or so surges during a race are quite manageable.

Predicting Performance

Climbing rate is proportional to a cyclist's power-to-weight ratio—watts per kilogram.

Bicycle weight, aerodynamics on flat sections, and drafting also modestly contribute to the demands of uphill riding.

Broadly speaking, two riders with the same power-to-weight ratio will climb at the same rate.

For example, a 122-pound rider who produces 235 watts (4.3 watts per kilogram) might be expected to climb about the same speed as a 138-pound rider who produces 265 watts (also 4.3 watts per kilogram).

Performance on stationary trainer can be used to predict race performance.

If the stationary-trainer-climbing performance and road-climbing performance of one rider is known, the stationary performance of another rider can be used to predict climbing performance of the second rider.

These concepts are illustrated in Figure 65 through Figure 69.

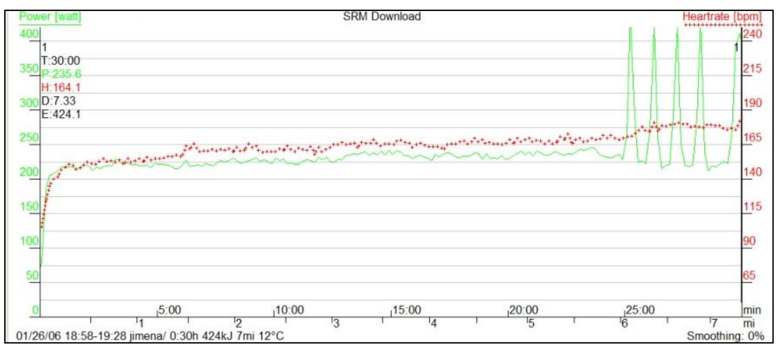


Figure 65. Standard HIT workout 4B. Rider JF. SRM download. Power, green; heart rate, red. This athlete weights 55 kilograms (122 pounds).

30-minute stand with 5 surges. Average power 237 watts. Watts per kilogram: 4.3.

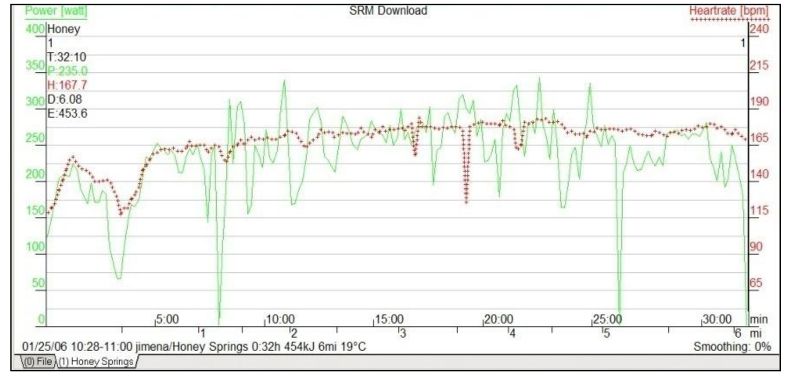


Figure 66. Race up Honey Springs Road, San Diego County, CA. Rider JF. SRM download. Power, green; heart rate, red.

Rider produces about the same amount of power in this race as in HIT 4B, Figure 65. Average power 235 watts. Watts per kilogram: 4.3. Finishing time 32:10.

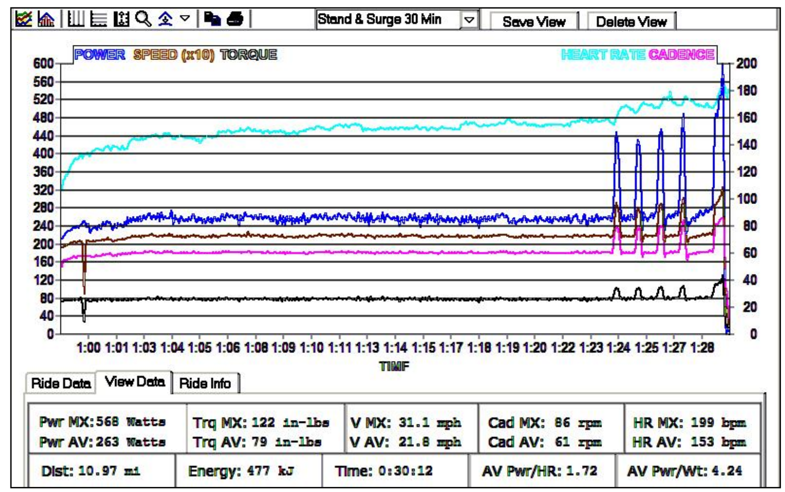


Figure 67. Standard HIT workout 4B. Rider AB. PowerTap download. From the top: Heart rate, turquoise; power, blue; speed, brown; cadence, pink; and torque, black. This athlete weighs 63 kilograms (136 pounds).

30-minute stand with 5 surges. Average power 263 watts. Watts per kilogram: 4.2.

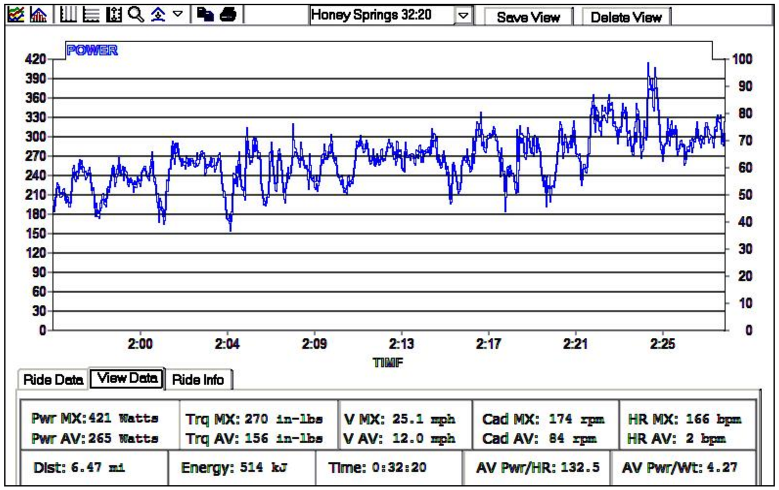


Figure 68. Race up Honey Springs Road, San Diego County, CA. Rider AB. PowerTap download. Power, blue. This athlete weighs 62 kilograms (136 pounds).

Rider produces about the same amount of power in this event as in HIT 4B, Figure 67. Average power 265 watts. Watts per kilogram: 4.3. Finishing time 32:20.

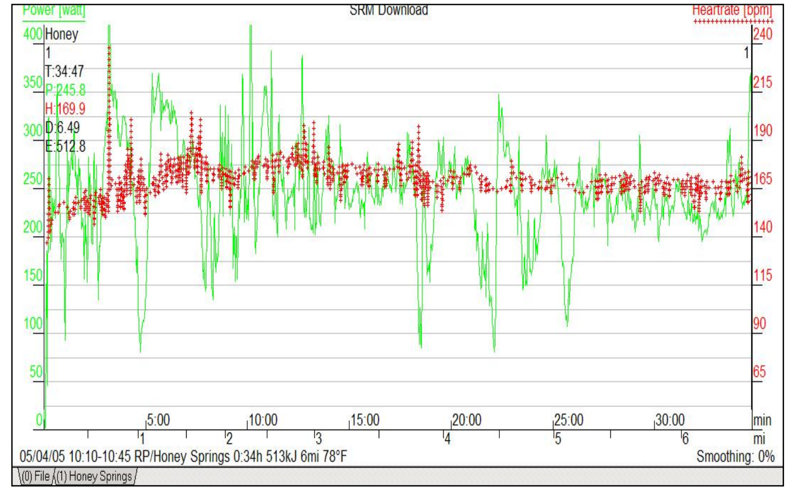


Figure 69. Race up Honey Springs Road, San Diego County, CA. Rider RP. SRM download. Power, green; heart rate, red. This athlete weighs 62 kilograms (136 pounds).

Average power 245 watts. Watts per kilogram: 4.0. Finishing time 34:47.

Again, performance on stationary trainer can be used to predict race performance.

Watts per kilogram can be used to predict performance when values change for an individual rider, or when comparing expected performance of two different riders.

For example, if one rider produces 4.3 watts per kilogram and climbs a hill in 32 minutes and 20 seconds (1,940 seconds), a second rider, producing 4.0 watts per kilogram, might be expected to climb the hill in 4.3 / 4.0 x 1,940 = 2,085 seconds = 34 minutes 45 seconds.

Within a few seconds, that was the result in comparing rider AB, Figure 68, and rider RP, Figure 69.

Heart Rate/Power Decoupling

As noted in *Heart-Rate-Based Training* beginning on page 36, fatigued riders may ride at lower or higher heart rates with the same power output.

You know how much absolute work you are doing because you have a power meter. You know how much relative work you are doing because you control your trainer setting, gears, and cadence.

Even though you may have a sufficient endurance base to perform the HIT™ program on Tuesdays (A workouts) and Thursdays (B workouts), perhaps with an endurance ride on Wednesday, you may find that on Thursdays your heart rate is lower for the same work—the same absolute or relative power.

If this is the case, perform the Thursday workouts based on workload (gearing and cadence, or watts) rather than heart rate.

If you are able to perform the work, there is no need to change your training.

If Wednesday's endurance ride prevents you from performing Thursday's work, back off Wednesday's intensity, volume, or both.

If you are still unable to perform Thursday B workouts' work, consider taking two days rest between workouts, reducing the volume of the workouts, or once-a-week workouts.

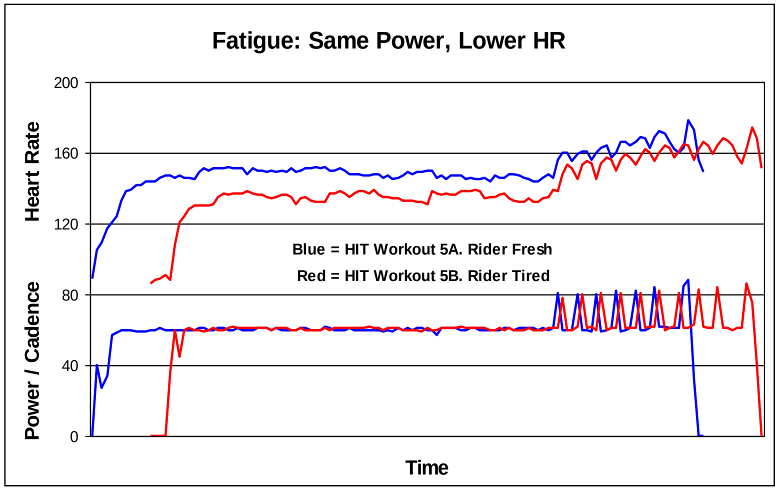


Figure 70. Reduction in heart rate with fatigue at same power output.

Standard HIT workouts 5A and 5B. Workout 5A includes 23 minutes of steady standing and seven surges. Workout 5B includes 20 minutes of steady standing and 10 surges. For more details about workout week 5, see page 157.

The two upper curves are heart rate recordings. The two lower curves are power (cadence) recordings. The higher heart rate recording (blue) is from workout 5A. The rider is fresh. The lower heart rate recording (red) is from workout 5B. The rider is tired. The two lower power recordings attest to the similar workloads.

Workout Too Hard?

It is hard to know precisely ahead of time how much work one can do during a workout session. Even riders with considerable experience may over or underestimate their abilities on any given day.

You may have planned a workout but be fatigued due to recent training or non-training stresses. Training stresses may include recently working harder than planned or completing a block (several continuous days) of training. Non-training stresses may include job-related, family, or financial problems.

The workload may also be different from expected. Although controlled settings—keeping gearing and cadence constant, the tire pressure the same, and the pinch-roller the same distance/pressure into the rear tire—allow generally repeatable power loads, sometimes just a small variation can change the power requirement of a previously determined exercise.

There are generally three approaches:

- Abort
- Tough it out
- Adjust

Abort

When you are clearly fatigued, it is generally best to allow recovery and not create a bigger problem. Forgoing a workout is sometimes a good idea.

The risk of not doing the workout might be the loss of a small amount of fitness. The risk of doing the workout might be overtraining and a much larger loss of fitness and motivation.

Aborting a workout may be an appropriate choice in dealing with too much work. However, if this occurs more than once a month, reexamine your training plan and its execution—there may be something wrong in your approach.

Tough it Out

Too many riders choose this option. Riders typically then perform mediocre work. The training is of marginal, if any, benefit.

Performing all scheduled intervals at relatively low intensity is sometimes a good approach: (1) When initially orienting and adapting to a training exercise, or (2) to keep volume up but allow for extra recovery before an event. (In peaking for major events, however volume is often reduced and the quality of intervals maintained.)

Toughing it out is generally a poor choice in dealing with too much work.

Adjust: Reduce the Volume of Intensity

This is often the best approach. There are several options:

- Reduce the intensity of some of intervals; perhaps perform high-quality work for one-third or one-half of the intervals.
- Cut back on the number of intervals.
- Increase the recovery between intervals.
- Where several different kinds of intervals are being performed, focus on the fitness systems that are least fatigued.

Example: Too Much Work

Figure 71 shows a partial heart-rate and cadence recording of a rider performing Standard HIT workout 7A. This workout includes 30 minutes of standing divided into 15 minutes of standing climbing tempo and 15 minutes with 15 surges. Surges are performed about 20 rpm faster than standing climbing tempo. Between surges, steady standing is maintained.

When it came time to perform Standard HIT workout 7B, heart rate and cadence recorded in Figure 72, a slight increase from the usual tire pressure translated into a 25-watt difference in the power requirement of the steady-stand exercise.

Although not recorded and shown in the figure, the athlete had a power meter and noticed the difference.

Steady standing at 60 rpm in the first heart-rate/cadence recording—Standard HIT workout 7A, Figure 71—was accomplished at 210 watts.

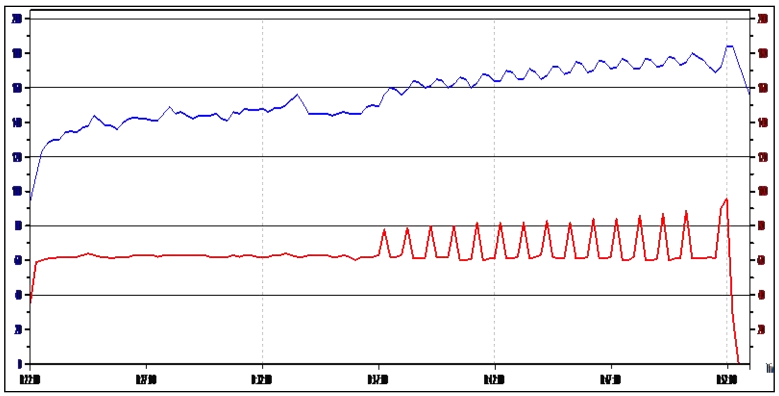


Figure 71. Standard HIT workout 7A. Heart-rate and cadence recording. Stand climbing tempo for 15 minutes directly followed by 15 standing surges. The upper (blue) curve is heart rate. The lower (red) curve is cadence. Stand performed at constant power. Surges to 80^{+} rpm. Constant cadence between surges.

In the second heart-rate/cadence recording—Standard HIT workout 7B, Figure 72—steady standing in the same gear and at the same cadence required 235 watts.

A relatively fatigued rider may face a similar inability to complete the surge exercise at pre-exercise determined cadences. Athletes without power meters might just assume they are fatigued.

The athlete decided to continue the workout as suggested and see what would happen.

What happened was the athlete could not accomplish the prescribed work and began to fail. There was not enough energy left to surge and keep intensity between surges as planned.

The choice was then to back off the surge efforts or back off the steady work between the surges.

If you need to back off because you get overextended, it is generally better to let your cadence fall between the surges than to reduce the quality of the subsequent surges.

Reducing the workload between surges helps keep the exercise high-quality.

This is what the athlete chose to do, letting his cadence fall from 60 rpm to about 50 rpm. This is illustrated in the second heart-rate/cadence recording (Figure 72).

HIT Workout 7A

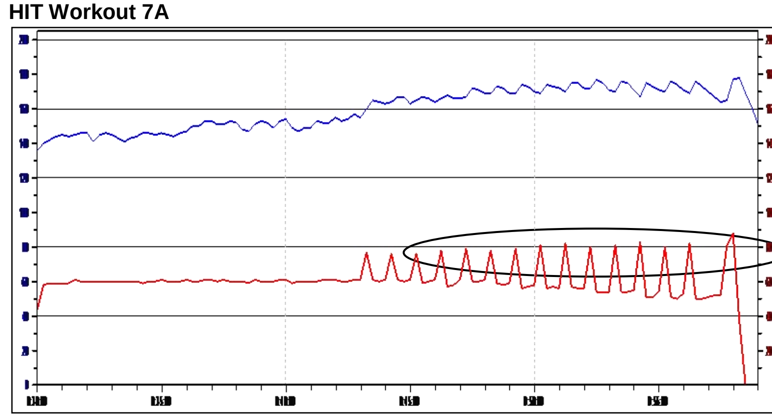


Figure 72. Standard HIT workout 7B. Heart-rate and cadence recording. Stand climbing tempo for 15 minutes directly followed by 15 standing surges. The upper (blue) curve is heart rate. The lower (red) curve is cadence. Stand performed at constant power. Surges to 80 rpm. Declining cadence between surges.

Tapering for Events

Tapering is reducing volume and/or intensity of training prior to competition. Most riders and coaches believe in the value of tapering for events.

Here is why, and here is how:

Why Taper?

Optimal event-day performance is a balance between being (1) recovered and rested, physically and mentally eager to race and (2) detrained—losing fitness from too little training.

The idea is to arrive at the event with all systems primed.

Tapering is reducing volume and/or intensity of training prior to competition. Multiple studies have shown that this improves performance.

Most coaches recommend reducing overall volume and volume of intensity, but keeping interval intensity high. That is to say: ride less, perform fewer intervals, but keep interval quality for the intervals performed.

Volume reduction may be 20% to 60%.

Balancing Training and Detraining

Consider these key points:

1. Glycogen energy stores take at least two days to be replaced after exhaustive aerobic exercise. More likely three.

   Exhaustive aerobic exercise occurs with a one-hour time trial at 90% of maximum heart rate or a two-hour ride at 85% of maximum heart rate.
2. No exercise in the 48 hours before events is associated with glycogen overload and muscle cramps in some athletes.
3. Muscle power is reduced by strength training for at least two weeks after maximum workouts. More likely three.

   Strength training includes weight work, one-legged riding, big-gear work, and anaerobic efforts.

   Eccentric exercise is especially damaging to muscles. Eccentric exercise occurs when muscles lengthen under tension. This is characteristic of some weight work and unaccustomed high-cadence work.

   General cycling is not an eccentric exercise. General running is. For this reason, among others, runners may need more of a taper than cyclists may.
4. Endurance lasts for at least 10 days. More likely two weeks.
5. It takes at least a week to recover from an unaccustomed long ride.
6. Maximum aerobic capacity lasts for a few days. Perhaps a week.

How to Taper

The key points provide the basis for the following recommendations:

1. The last endurance ride should be 7 to 10 days before the event.
2. Avoid exhaustive aerobic exercise for at least three days prior to the event.
3. Maximum weight work and maximum on-the-bike strength work should be avoided for at least three weeks before the event. Avoid unaccustomed eccentric exercise. Accustomed on-the-bike strength work can be continued until one week before the event but at no more than 75% of previous maximum power.
4. Continue aerobic intervals until 3 to 7 days before the event. Reduce the number of intervals by one-third.
5. Rest or active rest (easy riding) two days before the event.
6. Warm-up the day before your event to near event intensities.

Final Words

For many cyclists an effective taper turns out to be simply missing one workout and shortening another.

Following these suggestions should help you arrive at your event well rested, fit, and ready to do your best.

Part 4:
Standard (3-Month) HIT™ Program

The following three-month (13-week) program assumes at least a 4-month, 2,000-mile fitness base of endurance riding.

General information about the program, stationary training, examples of workouts with heart rate and cadence analysis, and a description of workout protocols follows. The workouts themselves begin on page 153.

The specific training program sequentially trains fitness systems for cyclists. During the 13 weeks, new exercises are added as others are dropped. It is generally a mistake for riders to perform the trainer workouts out of sequence. The systems progression is this way:

Program Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Neuromuscular—High-cadence	X	X	X	X	X	X	X	X	X	X	X	X	X
Strength—Isolated leg training	X	X	X	X	X	x							
Threshold				x	X	X	X	X	X	X	X	X	X
VO_2 max					x	x	X	X	X	X	X	X	X
Anaerobic										X	X	X	X

Table 27. HIT™ program sequential systems training.

It is common for most riders to miss a session here or there due to illness or due to work, family, or other commitments. This is expected; this is normal; this is good!

If occasional sessions are not missed due to such unplanned circumstances, almost all riders are advised to insert a recovery week about one-third of the way into the program, and insert another recovery week two-thirds of the way through the program.

Where to Workout

Workouts can be performed on stationary trainer, on a velodrome (track), on the road, or on dirt (cross-country). The stationary trainer is preferred. The environment is controlled; the rider can concentrate on the work to be done. Hints for logging your workout on stationary trainer are discussed on page 138.

Although environment specific workouts (velodrome, road, or dirt) are important, such workouts have limitations.

Track workouts do not allow for easily changed gear ratios, or the varied muscular stimulation that occurs between climbing and level-riding positions.

Road workouts are limited by changing terrain, traffic, traffic signals, potholes, and other considerations.

Dirt (cross-country) workouts are limited by changing terrain and rocks, ruts, and other obstacles.

Weekly Schedule

Two slightly different workouts are listed for each week.

For many cyclists, these two workouts are best performed on Tuesdays and Thursdays. For most riders, group rides commonly occur on the weekends. Schedule an endurance (long) ride on either Saturday or Sunday.

Few cyclists should perform more than three hard workouts a week. The twice-a-week high intensity workouts that follow, combined with a once-a-week endurance ride, provide a great weekly program for many riders.

Depending upon rider level, other training days may be devoted to additional endurance riding, recovery, skills training, cross-training, or comprehensive stretching.

Beginners

Riders who have not previously performed high-intensity training should modify the workouts. Options include:

1. Perform only half the volume of the workouts—performing only half the repetitions, or shortening endurance climbing by half.
2. Perform just one workout a week.
3. Do not perform most of the efforts at high-intensity.

Standard 3-Month HIT™ Program

Workout Protocols

In the high-intensity program that begins on page 153, I will use heart rate to help quantify aerobic workouts, and cadence to help specify neuromuscular (leg-speed) and strength workouts. Shorter anaerobic efforts are to be performed "all-out."

Gearing suggestions are just general indications of where you might be. As discussed under *Resistance Varies* on page 131, different trainers have different power curves. It is impossible to specify gearing precisely.

Power and torque ranges are also given. These are scaled to weight. As there is a great range in absolute fitness between, for example, a beginning 60-year-old woman, and a professional 25-year-old male, they are necessarily approximations.

The higher ranges apply to riders with a VO_2 max of about 70 milliliters per kilogram per minute. An example: A fit, regional elite male athlete such as a mid-pack US Cat 2 male racer.

The lower ranges apply to riders with a VO_2 max of about 50 milliliters per kilogram per minute. Examples include: Mid-pack beginning male racers; fit, established young masters female racers; or established old masters male riders. Said differently, examples include: A mid-pack US Cat 5 male racer; a US Cat 3, 35-year-old female racer; a 65-year-old US Cat 3 male racer.

For example, the exercise *stand climbing tempo* ranges from two to four-and-one-half watts per kilogram. For a 55-kilogram (121-pound) rider this is 110 to 220 watts. For a 70-kilogram (154-pound) rider this is 140 to 280 watts. A 121-pound 35-year-old Cat 3 woman might therefore climb steady tempo at 110 watts. A 154-pound Cat 2 man might therefore climb steady tempo at 280 watts.

For more information, see *Power-Based Training* on page 39.

Torque training applies to isolated-leg training and big-gear sprint training. Crank torque ranges are quantified, but vary greatly among riders. As with power ranges, these are scaled to weight.

The higher ranges apply to fit, regional elite male athletes. The lower ranges apply to beginning male racers; fit, established young masters female racers; or established old masters male riders.

PowerTap measures wheel torque, and SRM does not display its crank torque measurements.

- Torque in pound-inches is power in watts divided by cadence multiplied by 85. Alternatively:
- PowerTap users: To convert wheel torque to crank torque, use the formula:
  Crank torque = wheel torque x (chainring teeth / cog teeth), or use the table on 62.
- SRM users: Consider using a secondary program to view crank torque.

By noting PowerTap wheel torque or SRM power in a given gear, you can gain insight into your relative torque values from workout to workout.

For more information, see *Torque-Based Training* on page 53.

For more information on training and fitness standards for men and women, and masters by 5-year age groups, see the Appendix A: *Training & Fitness Standards for Excellence* starting on page 224.

The following is a brief description of the workout protocols used in the 3-month (13-week) HIT™ program that follows.

The beauty of some of these trainer class exercises is that they force you to do the right thing—it is not possible to do them "wrong."

Spin: A steady easy-gear interval at 100$^+$ rpm. Power less than 150 watts or 2 watts per kilogram.

Spin-up: A progressive exercise, increasing cadence 5 rpm every minute, 30 seconds, or 15 seconds, as indicated. Generally, use your easiest gear so that your ability to perform these exercises is not limited by heart rate or leg strength. Resistance on your trainer should be low. Power less than 150 watts or 2 watts per kilogram.

Spin wars: An occasional progressive exercise, increasing cadence 5 rpm every 10 seconds to maximum. A fun, generally group exercise. Caution: Attempt only when you have adapted to spin-ups. Generally, use your easiest gear so that your ability to perform these exercises is not limited by heart rate or leg strength. Resistance on your trainer should be low. Power should be less than 200 watts or 2.5 watts per kilogram.

ILT: Isolated leg training. Riding with one leg. The other leg is dangled, or supported on a stand or bike.

As you adapt, work on general leg strength by riding in moderate to big gears at 60 rpm. Initially heart rates will be below 75% for most riders. At moderate workloads, you will be able to concentrate on pushing down or pulling up. You may be able to ride in the aerobar position.

At hard workloads, you will not be as smooth. You will need to pull on the handlebars while you push forward or down with your leg. You will be using inertia to help get your leg back up for the next stroke. It is normal to hear a "whoomp" with each pedal stroke. If you are able to stay smooth, it means you are not training your downstroke quad and buttock muscles to their potential.

At high-power outputs, you will be pushing down with greater than body weight. Stabilize yourself with your arms. This is typically helpful at greater than 1.5 watts/kilogram. At greater than 2.0 watts/kilogram using both your hands on the same side of the handlebar as the leg performing the ILT makes the ILT easier to execute.

After adaptation, elite riders are able to perform this exercise at greater than 90% of maximum HR, at watts-per-kilogram power outputs of more than one-half their maximum ramped aerobic watts-per-kilogram power. For example, elite riders who have a maximum ramped aerobic power of 6 watts per kilogram are able to perform this exercise at 3.5 watts per kilogram.

3.5 watts per kilogram equates roughly to 5 pound-inches per kilogram of crank torque.

A cadence of 80 rpm, in an easy gear, preferentially works hip flexors and is more difficult for most riders to perform than 60-rpm work. The easy gear makes it more difficult to use inertia to help get your leg back up for the next stoke. A clunk at the bottom of the stroke reveals hip flexor weakness or lack of neuromuscular coordination. The 3-minute duration (for each leg) may be too long for beginners. Beginners may need to rest 15 seconds at the top of each minute.

Stand climbing tempo. Standing and other exercises to stimulate climbing muscles are best performed with the front of the trainer elevated 6 inches higher than the rear. Many riders use two 4x4 wood blocks to do this.

Big gear.

Cadence 50-60 rpm.

Heart rate: About 75% of maximum near the end of the stand.

Power: 2 to 4 watts per kilogram.

Chunk workouts into pieces to make it easier to focus. For example, you might chunk standing for 30 minutes into 5-minute sections. 2 minutes on the hoods, 1 minute on the tops, 1 minute on the drops, and 1 minute leaning on bars.

Beginners should sit for 30 seconds every 3 to 5 minutes.

Stand climbing is also important for accelerations and crotch and muscle relief, among others reasons. Most riders benefit from climbing in and out of the saddle. However, the majority of riders spend most of their riding time seated. Stand climbing helps make up for this deficit.

Standing surges. Stand as above. Surge 15 to 20 rpm faster for 15 seconds at the top of the minute. If surges to more than 20 rpm faster are easier, your resistance device may be maxed-out. Read more about this on page 132.

Keep standing for the 45 seconds at a cadence 50-60 rpm until the next surge. Heart rate will rise to 85^{+}% of maximum at the end of the last surge.

Power: Surges at 4 to 8 watts per kilogram.

The continuous standing requires mid-level aerobic work or better. It is easy to float seated exercises. If pedal tension if too low, you will plop down to your saddle. The surges get you to threshold or beyond.

For more information, including training variations, see page 122.

9-minute progressive intervals. Choose a moderate gear.

Cadence 90-100 rpm. Ride 3 minutes. Increase the gear one cog harder. Keep the same cadence. Ride 3 more minutes. Shift one cog harder once more. Ride 3 more minutes, same cadence.

If your gears skip a cog, e.g. 17 to 15, then reduce cadence by 5 rpm when you shift.

Vary hand position from drops to hoods to tops.

Heart rate: Aim for about 75% of maximum halfway (4.5 minutes) into the 9-minute interval. Heart rate at 80% to 85^{+}% of maximum at the end of the 9 minutes.

Power: 2.5 to 5 watts per kilogram during the last 3 minutes.

The progressive 9-minute intervals are a training trick to help teach you about the 3-4 minute intervals described next. They help you determine the gearing and cadence to use to achieve an effort you can sustain for 3 to 4 minutes.

For more information, including training variations, see page 120.

3- to 4-Minute Intervals. Read the information starting on page 113 and on page 115

In general, when you are able to finish 3- to 4-minute intervals in the 100 to 110 rpm range, shift to a harder gear next time. Pace within each interval and from interval to interval to perform near the maximum work possible for the total number of intervals prescribed.

Vary hand position from drops to hoods to tops.

Heart rate: Aim for 80^{+}% to 90^{+}% of maximum at the end of each interval.

Power: 2.5 to 5 watts per kilogram. Average power for the last four intervals above 30-minute time-trial power.

30-Second Sprint Intervals. Pace within each interval and from interval to interval to perform near the maximum work possible for the total number of intervals prescribed.

Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.

Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.

Sprint to 120 to 140 rpm.

Power at 3 to 10 watts/kg.

Crank torque at 1.5 to 5 pound-inches/kg.

For more information, see page 124.

15-Second Sprint Intervals. Perform these intervals almost “all-out” from the beginning of the intervals.

Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.

Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.

Although effort is anaerobic, do not expect anaerobic-level heart rates. (For more information about this, see page 38.)

Sprint to 120 to 140 rpm.

Power at 4 to 12 watts/kg.

Crank torque at 3 to 8 pound-inches/kg.

For more information, see page 124.

5-Second Sprint Intervals. Perform these intervals "all-out" from the beginning of the intervals. As soon as your cadence drops, stop.

Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.

Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.

Although effort is anaerobic, do not expect anaerobic-level heart rates. (For more information about this, see page 38.)

Sprint to 120 to 140 rpm.

Power at 5 to 15 watts/kg.

Crank torque at 5 to 13 pound-inches/kg.

For more information, see page 124.

Rest. In the exercises described below, generally, rest 1 minute between each exercise on a new line or where heart rate at the end of the interval is less than 75% of maximum.

Rest 2 minutes between each exercise group—exercises with a small paragraph space or where heart rate at the end of the interval is less than 80% of maximum.

Rest 3 minutes between individual and group exercises (sets and reps) where heart rate at the end of the interval is more than 80% of maximum.

Systems Trained by Workouts

As stated on page 148, the stationary trainer workout protocols sequentially train a number of cycling fitness systems. Table 28 lists fitness systems targeted in the standard 3-month HIT™ program and the exercises that train them.

Fitness System	Exercises
Neuromuscular	Spin-up Spin Maximum spin ILT, cadence 80 rpm
Muscular Strength Fast-twitch Slow-twitch Both	 5-second maximum power intervals ILT, cadence 60 rpm Stand climbing tempo ILT, cadence 60 rpm Standing surges
Threshold/metabolic	Standing surges 9-minute progressive intervals
VO_2	3- to 4-minute intervals
Anaerobic	30-second intervals 10 to 15 second intervals 5-second maximum power intervals

Table 28. Systems trained by workouts.

Standard 3-Month HIT™ Program

Week 1

Workout 1A, About 1.5 Hours

Spin 50 to 110 rpm. Increase 5 rpm every minute. Easiest gear. Say 39/27. Power <1.5 watts per kilogram. C.

Spin 60 to 125 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.

Spin 60 to 135 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/21. Power 1 to 3 watts/kg. Crank torque 1.5 to 4.5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.

Stand climbing tempo. 50-60 rpm. 10 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. HR about 75% of max at the end of the standing. HR/P.

Spin 5 minutes 100 rpm. Easiest gear. Say 39/27. Power <2 watts/kg. C.

Notes

Two slightly different workouts are listed for each week. Generally separate these two workouts by a day or two.

To understand the workout description, be sure to read the general information starting on page 105. Pay special attention to the Demo Stationary Trainer workout on page 136 and the Workout Protocols information on page 149. Remember that trainer setups vary, and that the power requirements for the same gearing and rpm are different on different trainer systems. Power, gearing, and rpm values are only suggestions.

Learn and adapt to exercises before performing them "all out."

Generally, rest 1 minute between each exercise on a new line.

Rest 2 minutes between each exercise group—exercises with a small paragraph space.

Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes. Experienced riders can end at 90% of max HR.

ILTs: Perform in various positions: each minute, alternate hands on the tops and in the drops.

Try to keep your knees in; practice this on the spins.

See examples of Week 1 heart-rate/cadence recordings starting on page 181.

Workout 1B, About 2 Hours

Spin 50 to 110 rpm. Increase 5 rpm every minute. Easiest gear. Say 39/27. Power <1.5 watts per kilogram. C.

Spin 70 to 130 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.

Spin 70 to 140 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/21. Power 1 to 3 watts/kg. Crank torque 1.5 to 4.5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.

Stand climbing tempo. 50-60 rpm. 12 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. HR about 75% of max at the end of the standing. HR/P.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/21. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. <50 watts. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.

Spin 60 to 120 rpm. Increase 5 rpm every 15 seconds. C.

Spin 5 minutes 100^{+} rpm. Easy gear. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 2

Workout 2A, About 1.5 Hours

Spin 50 to 110 rpm. Increase 5 rpm every minute. Easiest gear. Say 39/27. Power <1.5 watts/kg. C.
Spin 70 to 130 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.
Spin 70 to 140 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/21. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.

Stand climbing tempo. 50-60 rpm. 15 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. HR about 75% of max at the end of the standing. HR/P.

Spin 5 minutes 100^+ rpm. Easiest gear. Say 39/27. Power <2 watts/kg. C.

Notes

Two slightly different workouts are listed for each week. Generally separate these two workouts by a day or two.
To understand the workout description, be sure to read the general information starting on page 105. Pay special attention to the Demo Stationary Trainer workout on page 136 and the Workout Protocols information on page 149. Remember that trainer setups vary, and that the power requirements for the same gearing and rpm are different on different trainer systems. Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them "all out."

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^+% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes. Experienced riders can end at 90% of max HR.
ILTs: Perform in various positions: each minute, alternate hands on the tops and in the drops.
Try to keep your knees in; practice this on the spins.

See examples of Week 2 heart-rate/cadence recordings starting on page 183.

Workout 2B, About 2 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Say 39/27. Power <1.5 watts/kg. C.
Spin 70 to 130 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.
Spin 70 to 140 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

Stand climbing tempo. 50-60 rpm. 18 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. HR about 80% of max at the end of the standing. HR/P.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/19. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. <50 watts. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

Spin 60 to 120 rpm. Increase 5 rpm every 15 seconds. C.
Spin 5 minutes 100^+ rpm. Easiest gear. Say 39/27. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 3

Workout 3A, About 1.5 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.
Spin 70 to 135 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.
Spin 70 to 145 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

Stand climbing tempo. 50-60 rpm. 20 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. HR about 80% of max at the end of the standing. HR/P.

Spin 5 minutes 105^+ rpm. Easy gear. Power <2 watts/kg. C.

Notes

Two slightly different workouts are listed for each week. Generally separate these two workouts by a day or two.
To understand the workout description, be sure to read the general information starting on page 105. Pay special attention to the Demo Stationary Trainer workout on page 136 and the Workout Protocols information on page 149. Remember that trainer setups vary, and that the power requirements for the same gearing and rpm are different on different trainer systems. Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them “all out.”

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^+% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes. Experienced riders can end at 90% of max HR.
ILTs: Perform in various positions: each minute, alternate hands on the tops and in the drops.
Try to keep your knees in; practice this on the spins.

See examples of Week 3 heart-rate/cadence/power recordings starting on page 185.

Workout 3B, About 2 hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.
Spin 70 to 135 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.
Spin 70 to 145 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/19. Power 1.5 to 3.0 watts/kg. Crank torque 2.0 to 4.5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

Stand climbing tempo. 50-60 rpm. 25 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. HR about 80% of max at the end of the standing. HR/P.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. <50 watts. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/16. Power 2 to 4 watts/kg. (If you shift 2 teeth, say to 53/15, drop cadence by 5 rpm.) Crank torque 3 to 6 pound-inches/kg. P/T/C.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.
Spin 5 minutes 110^+ rpm. Easy gear. Power <2 watts/kg. C.
Spin wars. 100 to ??? rpm. Increase cadence 5 rpm every 10 seconds. Stop when you cannot increase more. Beginners about 140 rpm, expert spinners over 160 rpm. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 4

Workout 4A, About 1.75 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.
Spin 70 to 135 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.
Spin 70 to 145 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/16. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

Stand. 50-60 rpm. 25 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 5 minutes. This will double tempo power up to 8 watts/kg. HR about 87% of max at the end of the last surge. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 105$^+$ rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them "all out."

It is normal to be getting tired.
If you are looking forward to trainer and performing your best work yet for ILTs, by all means, kick it up a notch.
If you gave everything last week to ILTs, back off Workout 4A or 4B.
If you do not back off this week, plan to back off Workout 5A.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80$^+$% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes.
ILTs: Perform in various positions: each minute, alternate hands on the tops and in the drops.
Plan for HR to be at 75%-80% at end of steady standing, about 90% for last few surges.

See examples of Week 4 heart-rate/cadence recordings starting on page 187.

Workout 4B, About 2.25 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.
Spin 70 to 140 rpm. Increase 5 rpm every 30 seconds. Easiest gear. C.
Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/16. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

Stand. 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 5 minutes. This will double tempo power up to 8 watts/kg. HR about 90% of max at the end of the last surge. HR/P.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/16. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.
ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. <50 watts. T/C.
ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/15. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds.
Spin 7 minutes 110$^+$ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Week 5

Workout 5A, About 1.75 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/16. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/15. Power 3 to 6 watts/kg. Crank torque 2 to 4 pound-inches/kg. P/T/C.

Stand. 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 7 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 105$^+$ rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them “all out.”

If you did not back off a few gears for ILTs last week, do so on Workout 5A.

Plan to kick it up again on Workout 5B and have your hardest ILT session in a week—in Workout 6A, which will be the last ILTs for a while.

Generally, rest 1 minute between each exercise on a new line.

Rest 2 minutes between each exercise group—exercises with a small paragraph space.

Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80$^+$% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes.

ILTs: Perform in various positions: each minute, alternate hands on the tops and in the drops.

Plan for HR to be at 75%-80% at end of steady standing, about 90% for last few surges.

See examples of Week 5 heart-rate/cadence recordings starting on page 189.

Workout 5B, About 2.25 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/16. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/15. Power 3 to 6 watts/kg. Crank torque 2 to 4 pound-inches/kg. P/T/C.

Stand. 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 10 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. HR/P.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Moderate gear. Say 53/16. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. <50 watts. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/15. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.

Spin 10 minutes 115$^+$ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 6

Workout 6A, About 1.75 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Hard gear. Say 53/15. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Hardest gear ever. Say 53/14. Power 2 to 4 watts/kg. Crank torque 3 to 8 pound-inches/kg. P/T/C.

Stand 50-60 rpm. 20 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. HR/P.

4-minute interval. Cadence 90 to 100 rpm. 39/17. 2 to 5 watts/kg. Aim for HR about 80% of max by the end of the interval. Increase cadence 2 to 3 rpm each minute. Vary hand position drops to hoods to tops. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them "all out."

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes.
ILTs: Perform in various positions: each minute, alternate hands on the tops and in the drops.
Plan for HR to be at 75%-80% at end of steady standing, about 90% for last few surges.

Stop pedaling 15 seconds before starting 3- or 4-minute intervals.

See examples of Week 6 heart-rate/cadence/power recordings starting on page 190.

Workout 6B, About 2 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. Watch and record HR recovery every 30 seconds over next two minutes. HR/P.

9-minute progressive intervals. Perform 2 of these. Choose moderate gear. Cadence 90-100 rpm. Ride 3 min. Increase gear. Same cadence. Ride 3 more minutes, shift once more. Perhaps 39/17/16/15. 1.5 to 5 watts/kg. Aim for about 75% of max HR 4.5 minutes into the 9-minute interval. Aim to finish the first 9-minute interval at 80^{+}% of max HR. Aim for 85^{+}% of max HR by the end of the second rep. (If your gears skip a cog, e.g. 16 to 14, then reduce cadence by 5 rpm when you shift.) Vary hand position from drops to hoods to tops. HR/P.

4- minute intervals. Perform 2 of these. Cadence 90 to 100 rpm. Same gear as you finished 9-minute rep above—perhaps 39/15. 2 to 5 watts/kg. Aim for HR about 80-85% max by the end of each interval. Increase cadence 2 to 3 rpm each minute of each interval. Vary hand position drops to hoods to tops. HR/P.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.
Spin 10 minutes 115^{+} rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 7

Workout 7A, About 1.75 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. HR/P.

9-minute progressive interval. Choose moderate gear. Cadence 90-100 rpm. Ride 3 min. Increase gear. Same cadence. Ride 3 more minutes, shift once more. Perhaps 39/17/16/15. 1.5 to 5 watts/kg. Aim for about 75% of max HR 4.5 minutes into the 9-minute interval. Aim to finish at 85^{+}% of max HR. (If your gears skip a cog, e.g. 16 to 14, then reduce cadence by 5 rpm when you shift.) Vary hand position from drops to hoods to tops. HR/P.

4-minute interval. Cadence 90 to 100 rpm. Same gear as you finished 9-minute rep above—perhaps 39/15. 2 to 5 watts/kg. Aim for HR about 85^{+}% of max by the end of the interval. Increase cadence 2 to 3 rpm each minute. Vary hand position drops to hoods to tops. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them "all out."

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Stand climbing tempo: Beginners should sit for 30 seconds every 3 to 5 minutes.
Stop pedaling 15 seconds before starting 3- or 4-minute intervals.

Read more about 3- and 4-minute intervals on page 113 and page 115.

See examples of Week 7 heart-rate/cadence/power recordings starting on page 192.

Workout 7B, About 2 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. Watch and record HR recovery every 30 seconds over next two minutes. HR/P.

9-minute progressive intervals. Perform 2 of these. Choose moderate gear. Cadence 90-100 rpm. Ride 3 min. Increase gear. Same cadence. Ride 3 more minutes, shift once more. Perhaps 39/17/16/15. 1.5 to 5 watts/kg. Aim for about 75% of max HR 4.5 minutes into the 9-minute interval. Aim to finish the first 9-minute interval at 80^{+}% of max HR. Aim for 85^{+}% of max HR by the end of the second rep. (If your gears skip a cog, e.g. 16 to 14, then reduce cadence by 5 rpm when you shift.) Vary hand position from drops to hoods to tops. HR/P.

4-minute intervals. Perform 3 of these. Cadence 90 to 100 rpm. Same gear as you finished 9-minute rep above—perhaps 39/15. 2 to 5 watts/kg. Aim for HR about 85-90% max by the end of the intervals. Increase cadence 2 to 3 rpm each minute of each interval. Vary hand position drops to hoods to tops. HR/P.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.
Spin 10 minutes 115^{+} rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 8

Workout 8A, About 1.75 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 20 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. HR/P.

9-minute progressive interval.

Moderate gear. Cadence 90-100 rpm. Ride 3 min. Increase gear. Same cadence. Ride 3 more minutes, shift once more. Perhaps 39/17/16/15. 1.5 to 5 watts/kg. Aim for about 75% of max HR 4.5 minutes into the 9-minute interval. Aim to finish at 85^{+}% max HR. (If your gears skip a cog, e.g. 16 to 14, then reduce by 5 rpm when you shift.) Vary hand position from drops to hoods to tops.

Alternatively, keep the same gear and increase cadence 5 rpm every 3 minutes. HR/P.

Three 4-minute intervals. Cadence 90 to 100 rpm. 39/15. 2 to 5 watts/kg. HR 85^{+}% of max by the end of the first interval, higher for next two. Vary hand position from drops to hoods to tops. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them "all out."

You may well be getting tired if you have kept training miles the same. Decrease miles on other days to do quality trainer work. Ideally, keep a long ride in your schedule and decrease your medium rides. Total mileage should go down 10 to 20%.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Stop pedaling 15 seconds before starting 3- or 4-minute intervals.

Read more about 3- and 4-minute intervals on page 113.

See examples of Week 8 heart-rate/cadence/power recordings starting on page 195.

Workout 8B, About 2.25 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. Watch and record HR recovery every 30 seconds over next two minutes. HR/P.

9-minute progressive interval. Perform 1. Moderate gear. Cadence 90-100 rpm. Ride 3 min. Increase gear. Same cadence. Ride 3 more minutes, shift once more. Perhaps 39/17/16/15. 1.5 to 5 watts/kg. Aim for about 75% of max HR 4.5 minutes into the 9-minute interval. Aim to finish at 85^{+}% of max HR. HR/P.

Rest 3 minutes.

Six 3-minute intervals. Perform first 3 intervals one gear easier than you ended up in 9-minute interval above; last 3 intervals in same gear you ended up in 9-min interval above. Cadence 90 to 100 rpm. Increase cadence by 5 rpm in last minute of intervals 3, 5, and 6. Aim for HR about 80% of max by the end of the first interval, 90^{+}% of max by the end of the last interval. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. Vary hand position from drops to hoods to tops. HR/P.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.
Spin 10 minutes 115^{+} rpm. Power <2 watts/kg. C.
Spin wars. 100 to ??? rpm. Increase cadence 5 rpm every 10 seconds. Stop when you cannot increase more. Beginners about 140 rpm, expert spinners over 160 rpm. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Week 9

Workout 9A, About 1.75 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 20 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. HR/P.

Six 3-minute intervals. Cadence 90 to 100 rpm. Perhaps 39/15. 2 to 5 watts/kg. Aim for HR about 80$^+$% of max at end of first, higher for next two, 90%$^+$ for the last three. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. Vary hand position from drops to hoods to tops. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 105$^+$ rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them "all out."

You may well be getting tired if you have kept training miles the same. Decrease miles on other days to do quality trainer work. Ideally, keep a long ride in your schedule and decrease your medium rides. Total mileage should go down 10 to 20% from levels a month or two ago.

Generally, rest 1 minute between each exercise on a new line.

Rest 2 minutes between each exercise group—exercises with a small paragraph space.

Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80$^+$% of max.

Stop pedaling 15 seconds before starting 3- or 4-minute intervals.

Read more about 3- and 4-minute intervals on page 113 and page 115.

See examples of Week 9 heart-rate/cadence/power recordings starting on page 197.

Workout 9B, About 2 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Stand 50-60 rpm. 30 minutes. Big gear, perhaps 53/14. 2 to 4 watts/kg. 15 surges. Surge 15 to 20 rpm faster for 15 seconds at the top of each of the last 15 minutes. This will double tempo power up to 8 watts/kg. HR over 90% of max at the end of the last surge. Watch and record HR recovery every 30 seconds over next two minutes. HR/P.

Six 3-minute intervals. Cadence 90 to 100 rpm. Perhaps 39/15. 2 to 5 watts/kg. Aim for HR about 80$^+$% of max at end of first, higher for next two, 90%$^+$ for the last three. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. Vary hand position from drops to hoods to tops. HR/P.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.

Spin 10 minutes 115$^+$ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity

HR = Heart-rate percentage (aerobics) determines the intensity

P = Power determines the intensity

T = Torque determines the intensity

HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Weeks 10, 11

Workout A, About 1.5 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

New exercise: Stand 50-60 rpm. 3 minutes, as usual, big gear.
Then, medium gear. Probably two cogs easier and use the small ring.
12 sprints. Sprint to 120 rpm to 140 rpm for 15 seconds at the top of each minute for 12 surges (count to 30$^+$ pedal strokes). Perform sprints in various positions: in drops, hoods, and tops, leading from left and right leg, standing and sitting. Sit in between and pedal or not for 45 seconds. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. Although effort is anaerobic, do not expect anaerobic-level heart rates. P/T.

Six 3-minute intervals. Cadence 90 to 110 rpm. Perhaps 39/15 or 39/14. 2 to 5 watts/kg. Aim for HR about 80$^+$% max by the end of the first interval, higher for the next two, 90%$^+$ by the end for the last three. Power 2 to 5 watts/kg. Average power for the last four intervals above 30-minute time-trial power. HR/P.

Spin-up 60 to 125 rpm. Increase 5 rpm every 15 seconds; then back down and hold 5 minutes 110$^+$ rpm. Power <2 watts/kg. C.

Notes

Learn and adapt to exercises before performing them “all out.”

You may well be getting tired if you have kept training miles the same. Decrease miles on other days to do quality trainer work. Ideally, keep a long ride in your schedule and decrease your medium rides. Total mileage should go down 10 to 20% from levels a month or two ago.

Listed above are the same Workout A/Workout B workouts for two weeks. Although you can do both weeks of interval training, most riders should vacation one week from trainer. Then return to trainer for a peak of intensity training.

In the A workouts, the sprints come first. In the B workouts, the intervals come first. This trains fitness systems slightly differently and is valuable. Sprints are often best performed when fresh. On the other hand, sprints when fatigued more closely simulate the demands of racing.

Read more about sprint intervals on page 124.

See examples of Weeks 10 and 11 heart-rate/cadence/power recordings starting on page 198.

Workout B, About 2.25 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Six 4-minute intervals. Cadence 85 to 110 rpm. Perform the same work intervals you did on Workout A, but add a fourth minute. Do this by riding your first minute at 5 rpm below what would have been your first minute if you were only performing a 3-minute interval. Aim for HR about 80$^+$% max by the end of the first interval, higher for next two, 90%$^+$ by the end of the last three. Power 2 to 5 watts/kg. Average power for the last four intervals above 30-minute time-trial power. HR/P.

10 minutes rest/easy.

Stand 20 minutes, steady, big gear, 50-60 rpm. 2 to 4 watts/kg. HR/P.

Stand 50-60 rpm. 3 minutes, as usual, big gear. HR/P.
Then, medium gear. Probably two cogs easier and use the small ring.
12 sprints. Sprint to 120 rpm to 140 rpm for 15 seconds at the top of each minute for 12 surges (count to 30$^+$ pedal strokes). Perform sprints in various positions: in drops, hoods, and tops, leading from left and right leg, standing and sitting. Sit in between and pedal or not for 45 seconds. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. Although effort is anaerobic, do not expect anaerobic-level heart rates. P/T.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.
Spin 10 minutes 115$^+$ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Standard 3-Month HIT™ Program

Weeks 12, 13

Workout A, About 2 Hours

Spin 50 to 120 rpm. Increase 5 rpm every minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 70 to 150 rpm. Increase 5 rpm every 15 seconds. Easiest gear. Power <2 watts/kg. C.

Six 4-minute intervals. Cadence 85 to 110 rpm. Perhaps 39/15 or 39/14. 2 to 5 watts/kg. Aim for HR about 80$^+$% of max at end of first, higher for next two, 90%$^+$ for the last three. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. HR/P.

Stand 20 minutes, big gear, steady climbing. 2 to 4 watts/kg. HR 70-75% of max. HR/P. If time is constrained, this exercise may be omitted.

12 sprints.

Start in same gear as intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 4 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 4 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 4 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Although effort is anaerobic, do not expect anaerobic-level heart rates except perhaps for the 30-second sprints.

Spin 60 to 125 rpm. Increase 5 rpm every 15 seconds. C.

Spin 5-10 minutes 115$^+$ rpm. Power <2 watts/kg. C.

Workout B, About 2 Hours

Same as Workout A above.

Notes

Learn and adapt to exercises before performing them "all out."

Perform sprints in drops and on hoods, leading from left and right leg, standing and sitting. Read more about how to perform sprint intervals on page 124.

See examples of Week 12 heart-rate/cadence/power recordings on starting on page 200.

Week 14

Give yourself a pat on the back. You have completed 13-weeks of high-intensity training.

Do not try to keep up such training all year round. In fact, such a program twice a year is too much for many racers. (Lower-level intensity on stationary trainer can be performed all year round, if that is your preference.)

Plan on an easy week or two to recover.

Then, with your newfound fitness, you can start riding harder on the road, dirt, or velodrome—whether you prefer touring, endurance riding, mountain biking, hard group training, or racing.

Go reap the rewards of your hard work!

Workout Problems

Here are some examples of problems with workouts using heart-rate, cadence, torque, and power recordings from HIT™ workouts.

Poor Heart-Rate Strap Contact

No signal or interrupted heart rate pickup that improves through a training session is usually due to a lack of moisture contact with electrode sensors on the chest strap.

Sometimes the electrode contacts need some saliva, electrode gel, or some sweat-producing work to start functioning.

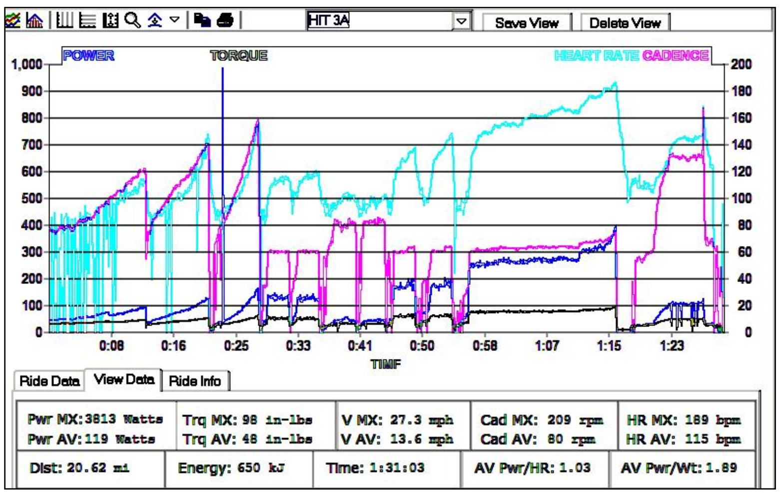


Figure 73. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black.

For the first 8 minutes of the session poor heart-rate strap contact results in an intermittent signal. As the athlete warms up and sweat creates a better electrode contact, signal pickup becomes steady.

A power-signal spike occurs at about 23 minutes. It is discussed on page 174.

Weak Heart-Rate Strap Battery

Interrupted or worsening heart rate pickup through a training session may be due to weak batteries.

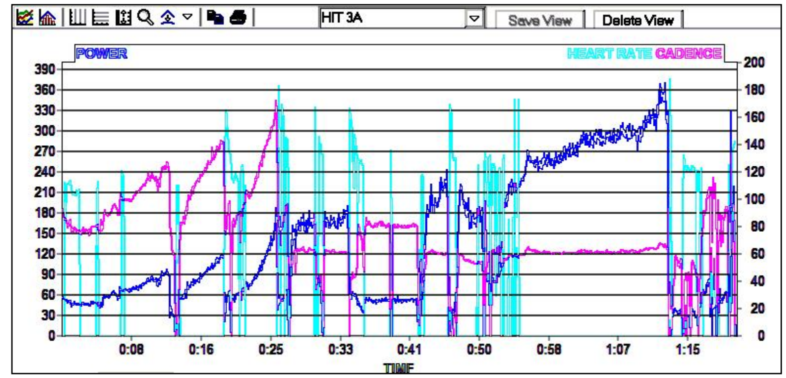


Figure 74. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; and power, blue. Heart-rate dropouts. The cadence and power recordings have no dropouts. Poor heart-rate strap signal is due to a weak chest strap battery.

Loss of Transmission Signal

PowerTap calculates power based on torque.

Weak batteries, conflicting transmission signals, and poor signal transmission or reception can all lead to torque dropouts. This results in power dropouts.

Dropouts have been a frequent problem on some PowerTap units. Improved hardware and self-correcting firmware have improved PowerTap readings.

Battery life for the PowerTap CPU and hub is short, sometimes less than 100 hours.

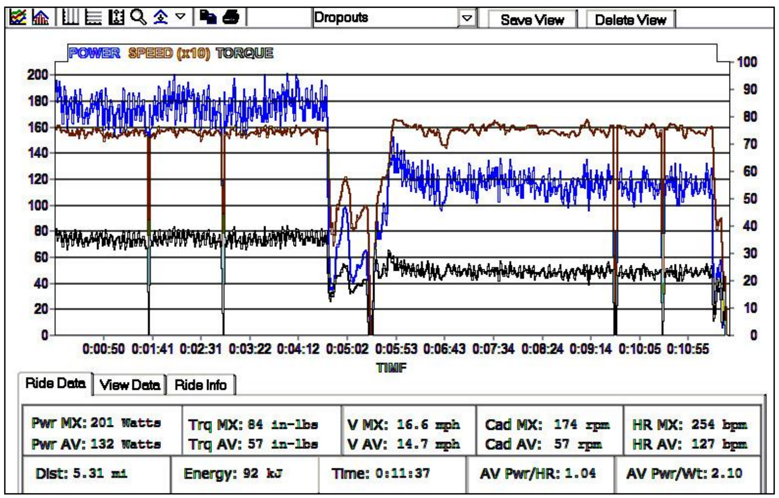


Figure 75. PowerTap download. From the top: Power, blue; speed, brown; and torque, black. Five dropouts are noted in this recording.

When dropouts exceed a few percent, as Figure 76 shows, calculated data averages may be misleading.

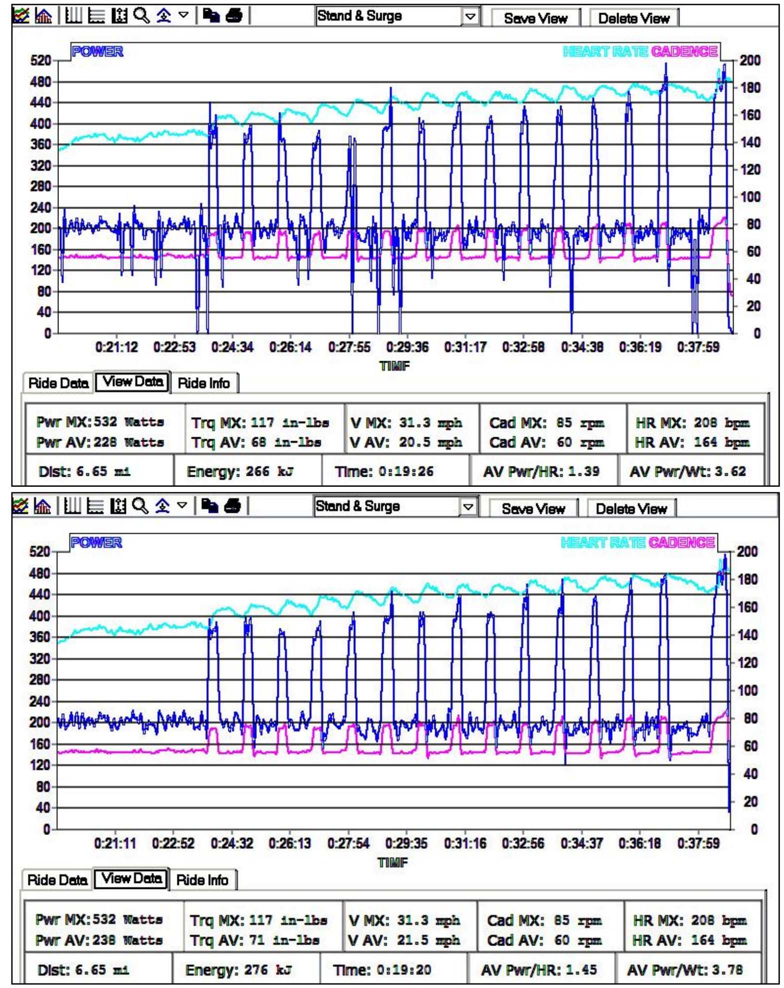


Figure 76. PowerTap download. Power, blue; heart rate, turquoise; cadence red. Standard HIT workout 8A. Multiple dropouts are noted in the top recording, where power averages 228 watts. When the errors are corrected, as in the bottom recording, power averages 10 watts more—238 watts.

Steps to take with dropouts, in suggested order, include:

- Check that the CPU is seated correctly squarely and firmly in its receiver shoe.
- Check the position of the PowerTap chainstay receiver unit.
  PowerTap has had several receiver unit versions. Each version has a preferred location. The preferred location may be written on the receiver unit or you may need to consult your owner's manual.
  Owner's manuals are available online at: http://www.cycleops.com/resources/instructionmanuals.htm.
- Manually recalibrate the torque to zero:
  - Set the CPU mode to WATTS and select (current) WATTS.
  - Press and hold the SELECT button for 2 seconds. WATTS will flash. The CPU will display torque in the top line.
  - While coasting downhill or while spinning the rear wheel, press and hold the SELECT button until the torque value reads zero.
  - Press and hold SELECT once to exit torque function.
- Check for conflicting transmission signals. Wireless cadence and speed sensors from other bicycle computers are frequent culprits.
- Replace both the CPU and hub batteries.
  The CPU uses a 2032 battery. To remove the cover, an American (Canadian) nickel (five-cent piece) works well; almost everything else, including screwdrivers, will destroy the soft plastic of the cover.
  The hub uses two N or 357 batteries.
- Assure battery contact.
  This is not usually a problem in the CPU.
  The mounting contacts for the hub N batteries may need to be bent out to improve contact.
  The 357 battery cradle may not be set correctly in its mount.
- Improve the contact between the CPU and receiver shoe.
  PowerTap has several receiver shoe versions.
  The mounting contacts of older receiver shoes may need to be bent out to improve contact.
  The contact points of the receiver shoe or CPU may need to be lightly sanded. An emery board nail file works well.
- Check the CPU and hub replacement batteries you installed above.
  Not all "new" batteries are fresh. Voltmeter readings should be at or above rated battery voltages.
- Check the torque on your rear axle. Of course, you want your wheel to be secure in the dropouts. However, high torque from an overtightened skewer or stationary trainer mount can cause dropouts.
- Replace the mounting hardware (receiver/wire/ receiver shoe).
- Contact PowerTap customer service. 1-800-783-7257.
  PowerTap customer service is good.
  You may need to send your unit back for servicing.

Power Readings Too High or Too Low

Use common sense. If values seem too high or too low, investigate.[53] Technologic and other recording errors occur with all of the power-measuring devices I have appraised.

For example, the PowerTap calculates power based on torque.

Ideally, the CPU recalibrates and resets torque automatically to zero during coasting.

This does not always happen.

1. Some PowerTaps have had problems with inadequate glue in their torque tubes. Such units may need replacement.
2. On stationary trainer, there may never be enough coasting for the CPU to recalibrate.

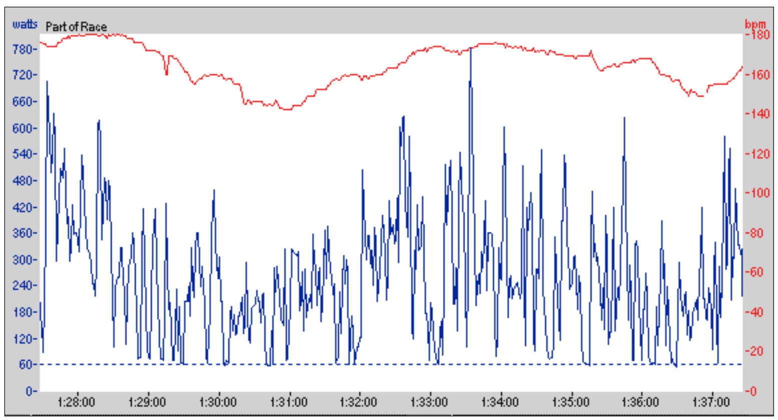


Figure 77. Power reading too high. Non-zeroing torque. PowerTap download. **Heart rate, red; power, blue. Power 60 watts too high. Whether pedaling or not, the power never drops below 60 watts (dotted line).**

[53] In a legal case in which I was an expert witness, an athlete and her coach claimed her power recordings demonstrated that she possessed Olympic-level fitness. Indeed, her recordings showed high values. However, as in Figure 78, her power-measuring device was incorrectly calibrated.

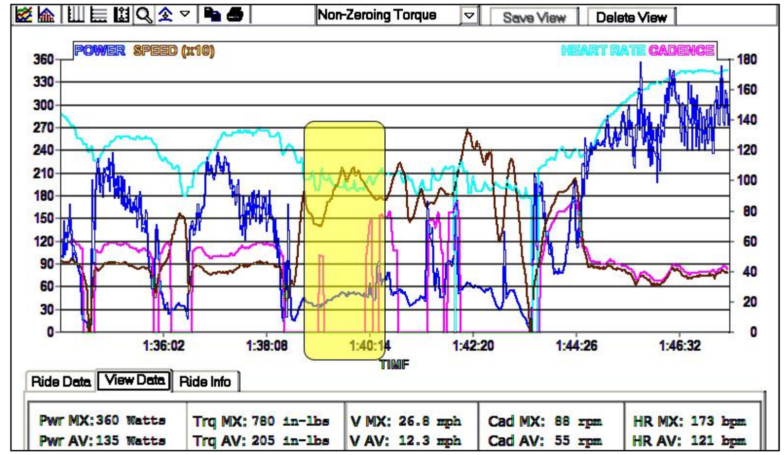


Figure 78. Power reading too high. Non-zeroing torque. PowerTap download. **Heart rate, turquoise; power, blue; cadence, pink; and speed, brown. Center of the highlighted area: The athlete is coasting downhill: Cadence is zero, speed is 21 mph, and heart rate is below 100. Power should read zero—but reads about 50 watts.**

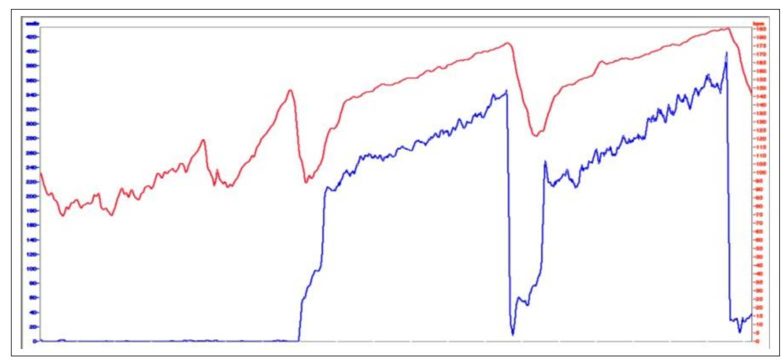


Figure 79. Power reading too low. Non-zeroing torque. PowerTap download. **Heart rate, red; power, blue. Stationary trainer workout: Two spin-ups, followed by two progressive 10-minute intervals. The athlete noticed his 10-minute efforts were displayed at unexpectedly low power levels. The spin-ups, performed in an easy gear, do not record any power. It is not possible to push the pedals without any power.**

The 10-minute effort recorded values also do not reflect the power produced by the rider. As the rider noticed, they are falsely low.

To recalibrate manually:

1. Set the CPU mode to WATTS and select (current) WATTS.
2. Press and hold the SELECT button for 2 seconds. WATTS will flash. The CPU will display torque in the top line.
3. While coasting downhill or while spinning the rear wheel, press and hold the SELECT button until the torque value reads zero.
4. Press and hold SELECT once to exit torque function.

HIT 13A SRM vs. PowerTap
Which is Right? Are Both Wrong?

Both SRM and PowerTap claim accuracy to about 2%.

Below is a workout an athlete performed using these two power-measuring devices at the same time, displayed with TrainingPeaks software.

Power is on the Y-axis. It is scaled from 0 to 600 watts.

Computed values, including averages for various intervals, can be found on the panels to the right of the tracings.

Overall

The images are of sufficient resolution to read reported values. Where print or monitor image display makes values hard to read, you may be able to zoom the page on your monitor to read the values easily.

Unlike the problems noted in Figure 77, Figure 78, and Figure 79, there is no elevated baseline or zero-power with pedaling to see easily that there is an apparent problem on either device.

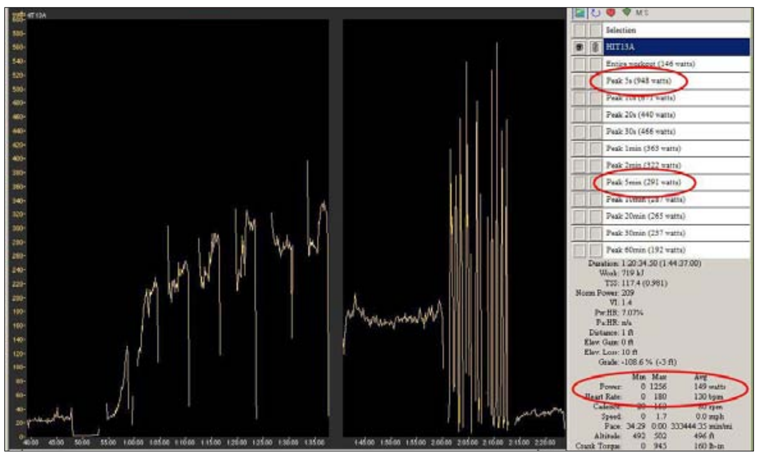


Figure 80. SRM download. HIT13A. Power tracing from entire workout. Power averages 149 watts. Peak 5 seconds is 948 watts. Peak 5 minutes is 291 watts.

Throughout the workout, the SRM records and generally displays values higher than the PowerTap.

An important problem is that the discrepancy is not constant.

This is a challenging problem, as discussed below under *Steady Efforts, Different Differences*.

For the overall workout, the SRM display (Figure 80, circled on the panel to the right of the tracing, lower quarter) shows the average to be 149 watts, the PowerTap (Figure 81) 119 watts. This is a difference of 30 watts.

Looking at the peak 5-minute and 5-second values, the SRM (Figure 80, circled on the panel to the right of the tracing, top half) shows the peak values as 291 and 948 watts respectively; the PowerTap (Figure 81) 236 and 927 watts. These are differences of 55 watts and 21 watts.

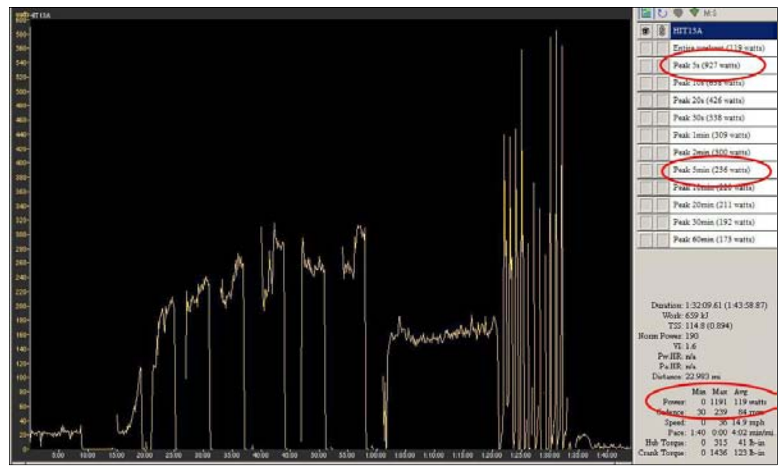


Figure 81. PowerTap download. HIT13A. Power tracing from entire workout. Power averages 119 watts. Peak 5 seconds is 927 watts. Peak 5 minutes is 236 watts

Steady Efforts, Different Differences

During the last 4-minute interval, the SRM display (Figure 82) shows the average power to be 299 watts, the PowerTap (Figure 83) 277 watts. This is a difference of 22 watts.

During the steady stand, approximately 20 minutes, the SRM (Figure 84) shows the average power to be 171 watts, the PowerTap (Figure 85) 161. This is a difference of 10 watts.

During the final easy spin, the SRM (Figure 86) shows the average power to be 34 watts, the PowerTap (Figure 87) 7 watts. This is a difference of 27 watts.

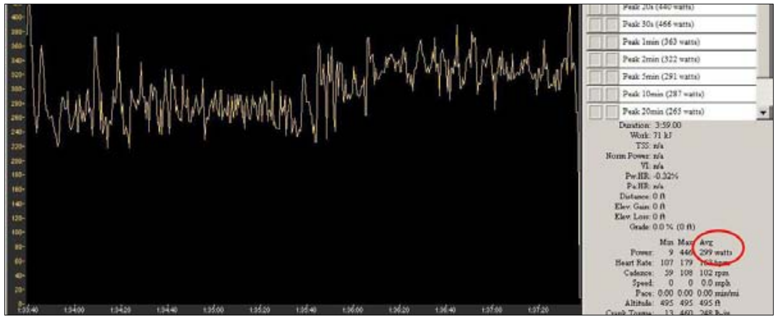


Figure 82. SRM download. HIT13A. Last 4-minute interval. Average power for the interval, circled in red, is 299 watts.

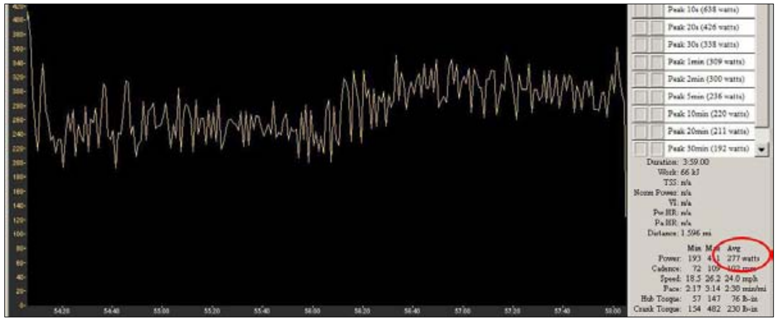


Figure 83. PowerTap download. HIT13A. Last 4-minute interval. Average power for the interval, circled in red, is 277 watts.

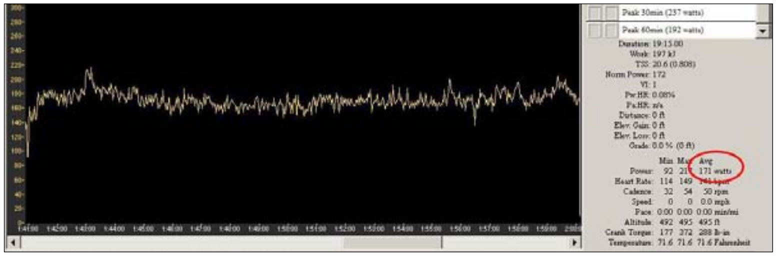


Figure 84. SRM download. HIT13A. Steady stand. Average power, circled in red, is 171 watts.

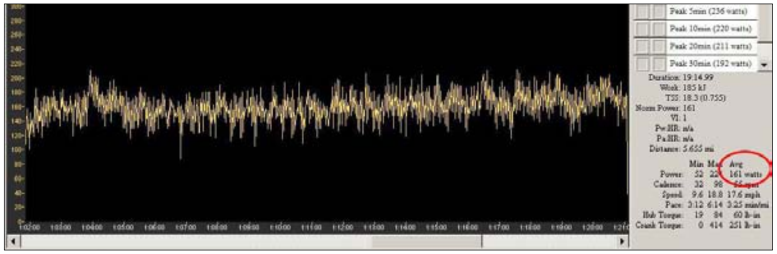


Figure 85. PowerTap download. HIT13A. Steady stand. Average power, circled in red, is 161 watts.

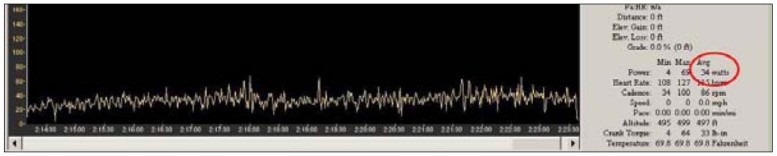


Figure 86. SRM download. HIT13A. Final easy spin. Average power, circled in red, is 34 watts.

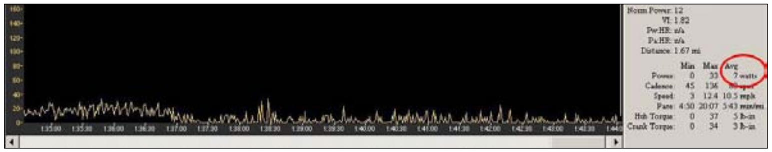


Figure 87. PowerTap download. HIT13A. Final easy spin. Average power, circled in red, is 7 watts.

Table 29 summarizes the recorded overall, 5-minute, 5-second, and steady effort averages. The differences between the SRM and the PowerTap averages do not follow a constant pattern.

Effort	Intensity	SRM	PowerTap	Difference	
		Watts	Watts	Absolute Watts	%
Overall		149	119	30	22%
Best 5 minutes		291	236	55	21%
Best 5 seconds		948	927	21	2%
Final Spin	**Easy**	34	7	27	131%
Steady Stand	**Moderate**	171	161	10	6%
Last 4' Interval	**Hard**	299	277	22	8%

Table 29. Steady-state discrepancies.

If, with increasing effort, there was a constant difference, either in absolute or percentage values, one might ascribe the difference to a calibration error.

There are two typical calibration problems: offset and slope.

Figure 88 illustrates these problems.

Older SRM and PowerTap units often require daily manual offset calibration. Although these functions are now automated in theory, such problems are still frequently an issue for riders using stationary trainers—where freewheeling may be infrequent or short—and automatic offset calibration does not occur.

For SRM, slope values are generally determined at the factory, and written onto the back (inner chainring area) of the unit. They are generally three-digit numbers between 12.0 and 35.0. However, units may be mislabeled, riders may transcribe them incorrectly to their PC programs, or values may change with time.

Regardless, offset or slope systematic errors do not explain the unpredictable differences recorded in Table 29, where differences do not remain constant, constantly increase, or constantly decrease.

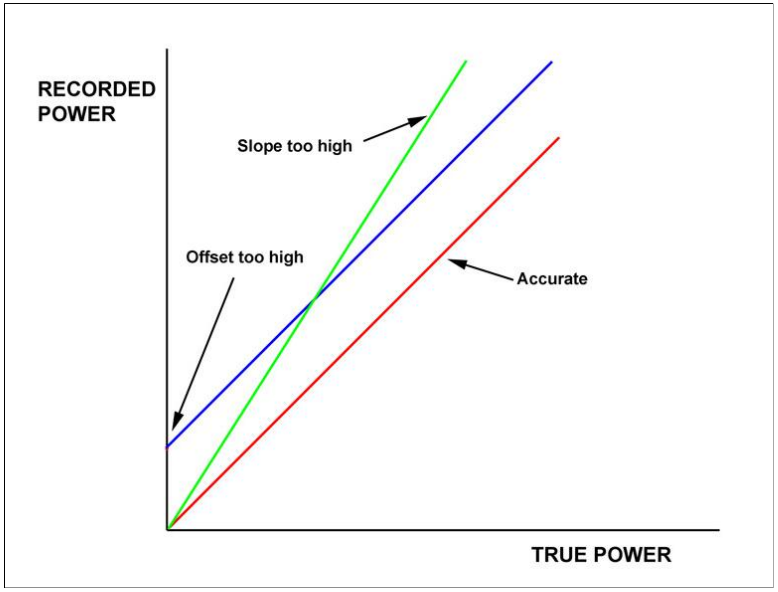


Figure 88. Systematic errors. The red line represents an accurate recording. Offset (blue) or slope (green) errors result in predictable recorded errors.

Sprint Efforts

In assessing sprint performance, racers and coaches may snoop displays, looking to see how many efforts exceeded a specific wattage. Here the program is set *not* to smooth the data.

During the 12 sprints, the SRM display, Figure 89, shows that 6 of the sprints exceeded 500 watts, and 2 additional sprints were almost at that level.

The PowerTap display, Figure 90, shows 7 of the sprints exceeded 500 watts, and 2 additional sprints were almost at that level.

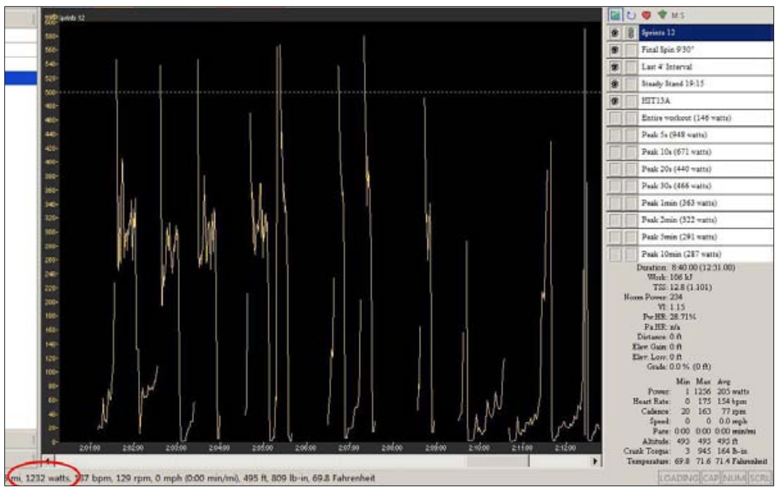


Figure 89. SRM download. HIT13A. Twelve sprints. Six (almost eight) sprints display over 500 watts. Power output appears to average less in the last six sprints. The white cursor over the last sprint has an associated output of 1232 watts, shown circled in the bottom left corner, though the yellow watts display is about 350 watts.

TrainingPeaks software is well known to display peaks inaccurately, even in stacked graph format. In order to better determine peaks one must look at the raw data or forward the cursor data bit by data bit.

In Figure 89, the cursor is over the last sprint of the SRM display. Though the display suggests that the peak wattage for this sprint was about 350 watts, as circled in the bottom left of the figure, the power output was recorded as 1232 watts.

In Figure 90, the cursor is over the last sprint of the PowerTap display. Though the display suggests that the peak wattage for this sprint was about 480 watts, as circled in the bottom left of the figure the power output was recorded as 1154 watts.

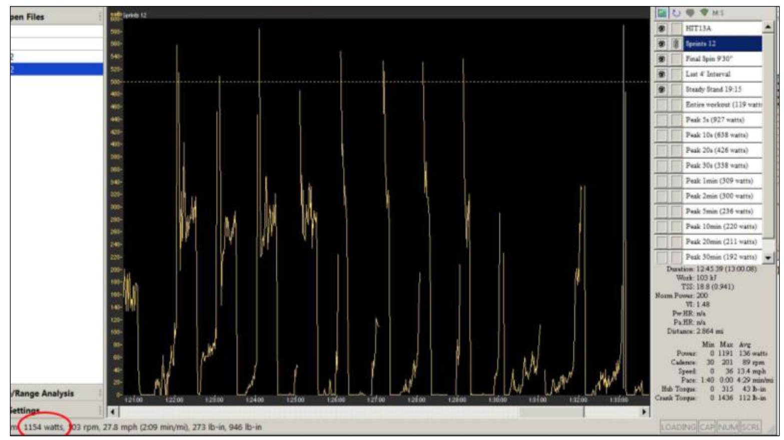


Figure 90. PowerTap download. HIT13A. Twelve sprints. Seven (almost nine) sprints display over 500 watts. Power output appears to average less in the last six sprints. The white cursor over the last sprint has an associated output of 1154 watts, shown circled in the bottom left corner, though the yellow watts display is about 480 watts.

As stated above, in order to determine peaks better, one must forward the cursor data bit by data bit or look at the raw data. The raw data provide the most accurate values.

Both methods show substantially higher values than those observed by looking at horizontal or stacked graphs—about double. For SRM, the cursor values displayed are lower than the raw data bits. For PowerTap, the values are identical.

A glance impression, of both the SRM and PowerTap display images (Figure 89 and Figure 90), is that peak power was lower in the last six than in the first six sprints. As more PowerTap sprint peaks exceed 500 watts, one might think that PowerTap is recording higher sprint peak values.

As Table 30 shows, both of these impressions are incorrect. The power recorded by the SRM was higher in every sprint. The power recorded on the last six sprints was higher than the first six for both the SRM and the PowerTap.

Sprint	SRM		PowerTap	
	Cursor	Raw Data	Cursor	Raw Data
1	893	921	837	837
2	928	928	846	846
3	898	916	896	896
4	967	975	941	941
5	1083	1091	953	953
6	1009	1034	935	935
7	1135	1194	1134	1134
8	1168	1170	1094	1094
9	1188	1204	1137	1137
10	1199	1256	1191	1191
11	1200	1201	1125	1125
12	1216	1247	1154	1154

Table 30. Peak values recorded (though not displayed) during 12 sprints.

SRM vs. PowerTap Summary

These recordings demonstrate that power-measuring devices may display and record differences greater than that accounted for by their claimed accuracy of about 2%.

The source of the differences in these recordings is uncertain, but it is of concern to riders and coaches who rely on such recordings for training or racing decisions.

Power Transmission Spikes

Surges in transmission signal occasionally occur. Where effort has been steady, ignore such blips, or manually correct errors in raw data files (such as PowerTap Excel files) or with software.

A signal spike occurs in the workout shown in Figure 73, zoomed in Figure 91 below.

The VIEW DATA panel indicates a spike in power output to 3813 watts.

The spike *is not* a problem in viewing the whole workout, as in Figure 73.

The spike *is* a problem in zooming and examining the details of the spin-up intervals, as in Figure 91 below. The power and torque lines are compressed to near the bottom of the X-axis.

Error correction will fix the problem. Software error correction is easy with SRM, moderately-easy with Polar, and cumbersome with PowerTap.

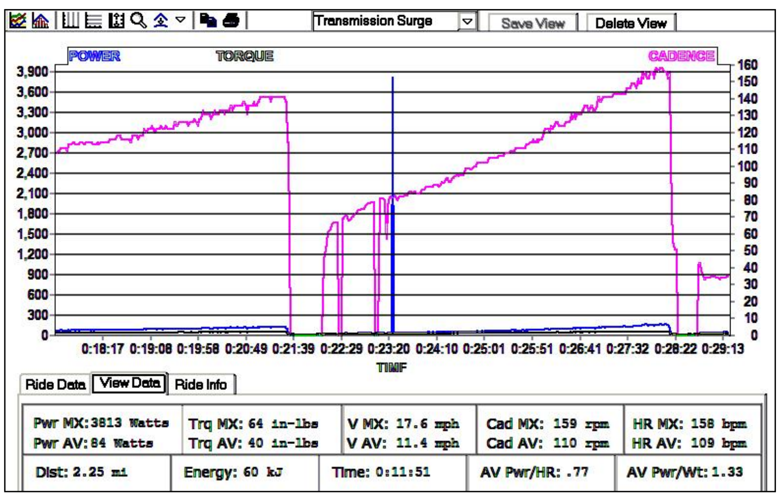


Figure 91. PowerTap download. From the top: Cadence, pink; power, blue; and torque, black. A power spike to 3813 watts at 23:20 sets the Y-axis limit at 3,900 watts and compresses the power and torque curves for the rest of the values to the bottom of the graph.

Program Drawing Errors

Almost all software applications will occasionally misdraw.

In the example below, an overview of a 90-minute HIT workout shows cadence in the second spin-up to 180 rpm. A zoom view shows that only 150 rpm was achieved.

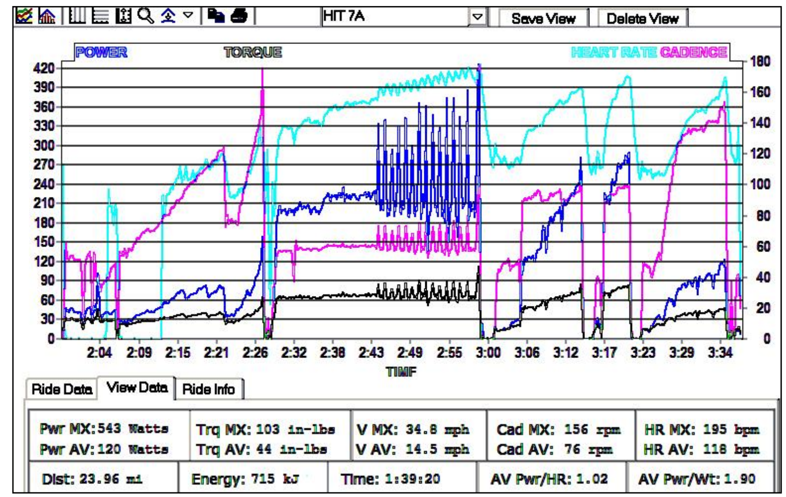


Figure 92. Standard HIT workout 7A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black.

This rider performs the first spin-ups as directed, 50 to 120 rpm; the second from 80 to 150 rpm.

The program draws incorrectly. The graph shows the cadence in the second spin up to 180 rpm. The VIEW DATA report shows maximum cadence for the entire workout at 156 rpm.

When the spin-ups are zoomed, as in Figure 93 at right, the cadence function is correctly drawn.

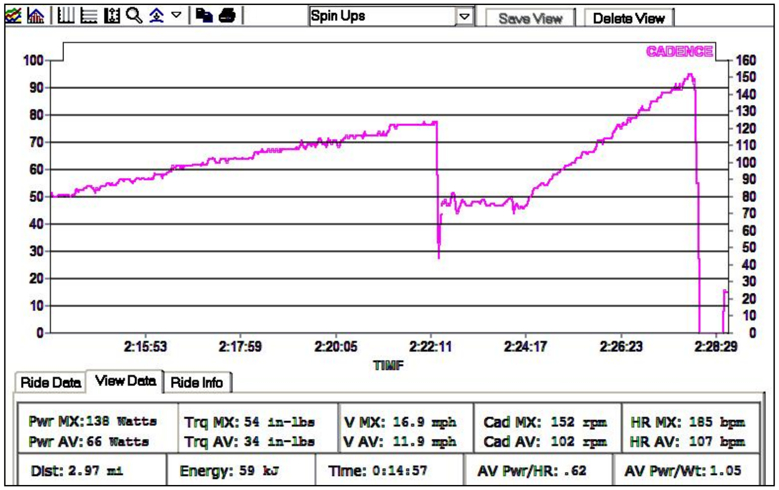


Figure 93. Zoom from above workout: Spin-Ups:

This rider performs the first spin-ups as directed to 120 rpm; the second from 80 to 150 rpm.

Unlike Figure 92 at left, the program now draws correctly.

In the example below, an overview of Standard HIT workout 10B includes 12 sprints. The overview does not show that the sprints were paced—each successive sprint performed at a higher power output than the previous. A zoom view shows that each sprint successive sprint was performed at a higher power output.

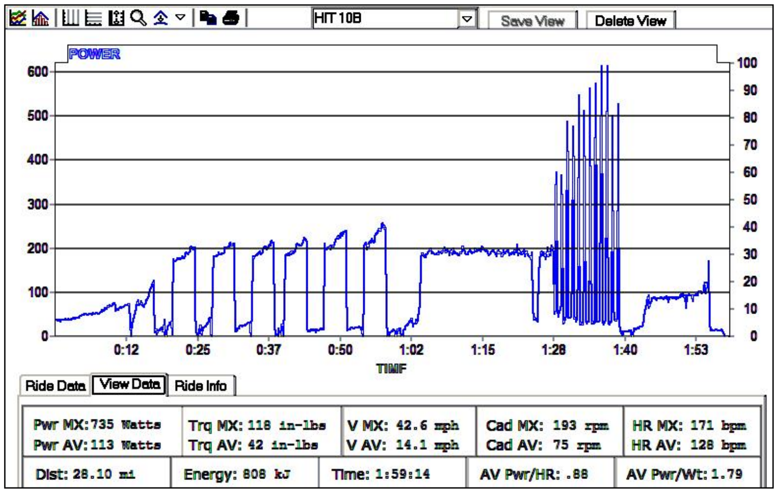


Figure 94. Standard HIT workout 10B. PowerTap download. Power, blue.

This rider performs the 12 sprints, starting at about 1:30, as directed: each successive sprint at a higher power output than the previous.

The program draws incorrectly. The graph shows the 9th and 10th sprints as achieving the highest power outputs, about 600 watts.

When the sprints are zoomed, as in Figure 95 at right, the power function is correctly drawn.

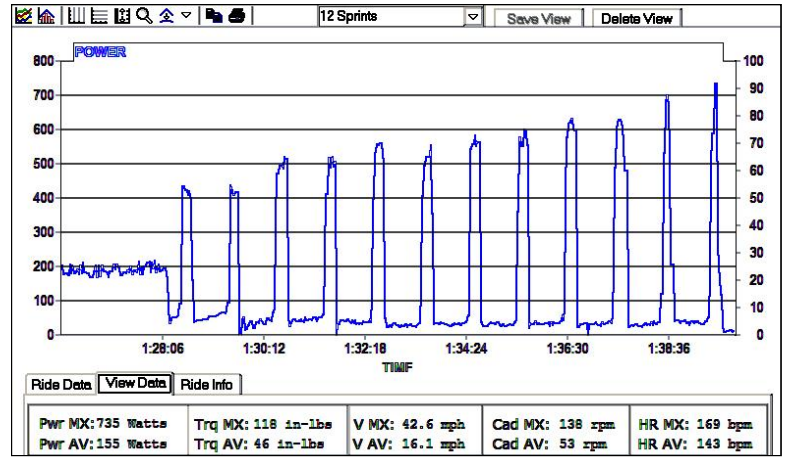


Figure 95. Zoom from above workout: 12 sprints:

This rider performs the sprints as directed, each successive sprint a little harder than the previous.

Unlike Figure 94 at left, the program now draws correctly. The 11th and 12th sprints are performed at the highest power outputs, over 700 watts.

Zigzag Power or Torque

When power meter software displays or records data based on a non-whole (fractional) number of pedal strokes, a zigzag power or torque value may be observed.

Consider isolated-leg (one-legged) training at 60 rpm with PowerTap, a device that samples every 1.2 seconds. Every wattage result displayed/recorded is the result of 1.2 pedal strokes.

When the timing starts on the first part of the downstroke, the overall average power is higher. When timing starts on the first part of the upstroke, average power is lower.[54] Successive swings create a zigzag effect.

The result is technically called a precession artifact and looks like Figure 96.

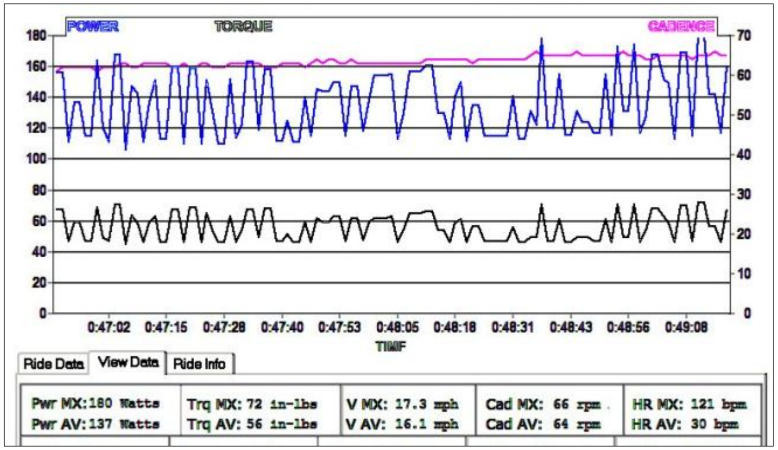


Figure 96. 60-rpm isolated-leg (one-legged) training.
Power, blue, averages 137 watts.
The zigzag pattern is an artifact, due to a computational precession effect.
Many swings are about 50 watts.

---

[54] We can estimate the expected swings.

Suppose power is steady and averages about 137 watts. As a rough approximation, power is double on the downstroke and absent on the upstroke.* When starting on the downstroke, one might expect to average about 274 x 0.2 = 55 watts more over 1.2 strokes or about 46 watts more per stroke. The power reading might therefore show a maximum of 137 + 46 = 183 watts.

When starting on the upstroke one might expect to average the same 137 watts, but now for 1.2 strokes. The power reading might therefore show an absolute minimum of 137 ÷ 1.2 = 114 watts per stroke.

Therefore, the maximum difference over several minutes might be expected to be about 183 – 114 = 69 watts. Most zigzag swings will be less—since tracings will rarely result from purely extra downstrokes next to purely extra upstrokes.

In Figure 96 above, the highest value recorded is about 175 watts; the lowest value is about 105 watts—resulting in about a 70 watts difference.

*The highest and lowest values are about 10 watts lower than expected. This may be because downstroke forces are less than double and upstroke forces are negative—inertial wheel forces pull the leg around.

Too Much Trainer Load

Some exercises are best performed under low load (watts). For example, spins, spin-ups, and easy gear isolated leg exercises.

For spin-ups, generally use your easiest gear so that your ability to perform spin-ups is not limited by heart rate or leg strength.

Resistance should be low: Power less than 150 watts or 2 watts per kilogram.

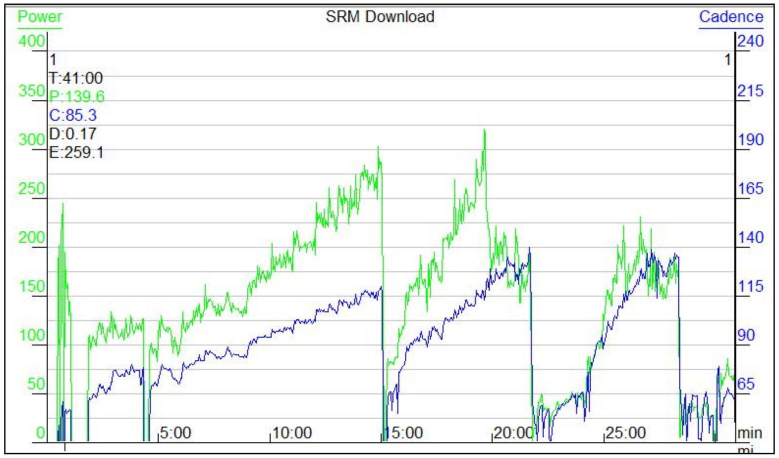


Figure 97. Standard HIT workout 1B. SRM download. Power, green; cadence, blue. Too hard a gear creates power demand (275 watts) that limits cadence.

Not Enough Trainer Load

The stand climbing tempo exercise is performed at 60 rpm. If your biggest gear is 53/12, you will be riding at about 22 miles per hour.

If at 22 miles per hour, the trainer creates a load of 230 watts, and you can climb tempo on the road at 300 watts, it will not be possible to perform the exercise correctly on the trainer.

Sometimes a bigger chainring (for example, a 55) or a bigger cog (for example, an 11) or both may help. Alternatively, you may need a different trainer.

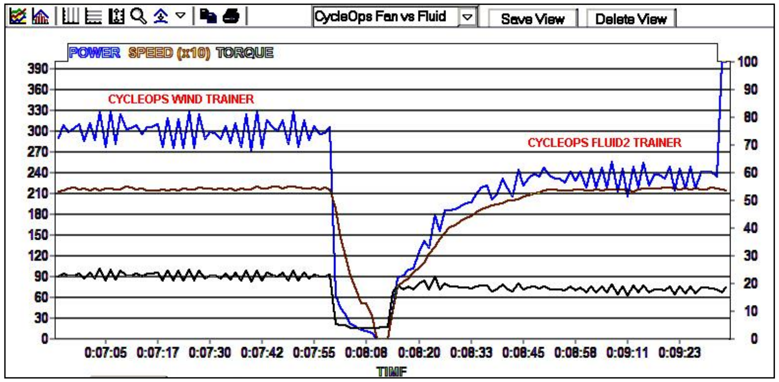


Figure 98. Two trainers, different loads. CycleOps Wind trainer on the left; CycleOps Fluid2 trainer on the right. From the top: Power, blue; speed, brown; and torque, black.

The trainer on the left creates a load of about 300 watts at 22 miles per hour. The trainer on the right creates a load of about 230 watts at the same speed.

Starting Interval Too Hard

Starting out too hard is a common problem—and one which power meters help correct.

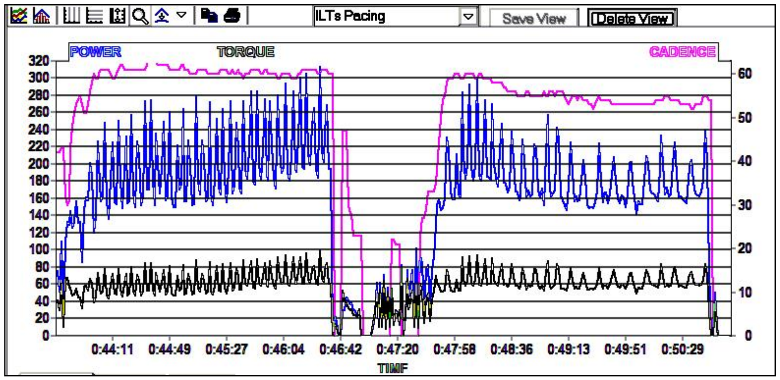


Figure 99. Interval pacing. ILTs. PowerTap download. From the top: Cadence, pink; power, blue; and torque, black.

The first ILT (isolated-leg training) interval, left, is paced well—with gradually increasing power. The second ILT interval is begun too ambitiously, and power drops as the interval progresses.

Mid-Interval Dips, Lack of Pacing

Loss of concentration or mid-interval dips are common.

Average interval power is usually more important than peak interval power. Some athletes sprint at the end of intervals to try to see high power numbers, rather than focusing on interval averages.

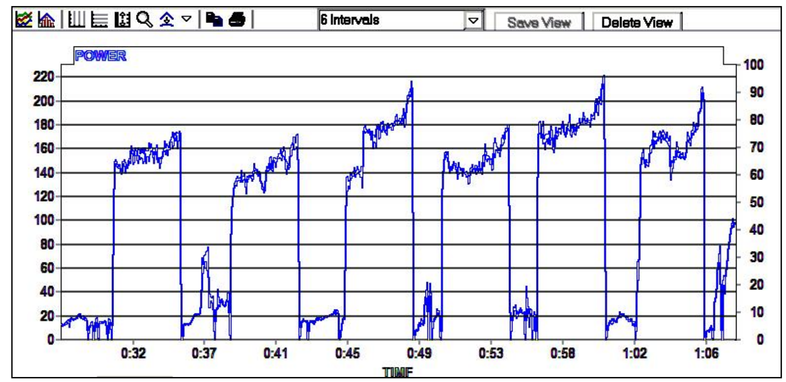


Figure 100. Suboptimal intervals. PowerTap download. Power, blue. Dips in power in the middle of fourth and sixth interval as the athlete loses focus. Surges at the end of intervals 3, 4, 5, and 6. See the discussion in the text, and contrast with Figure 101.

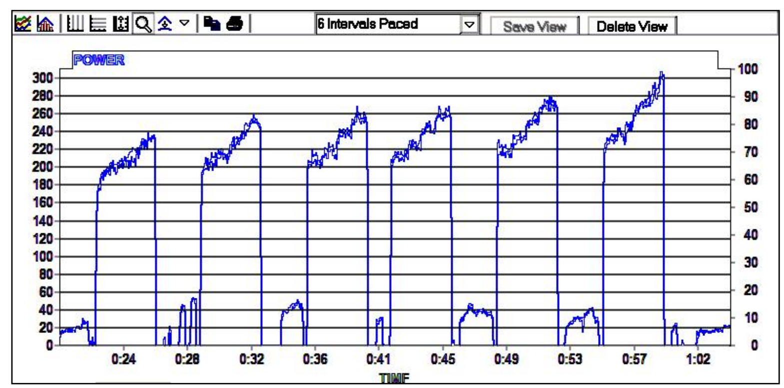


Figure 101. Six intervals paced well. PowerTap download. Power, blue. See also *3- to 5-Minute (VO2) Intervals* on page 115.

Summary

Power and heart-rate monitors benefit riders and coaches in allowing workouts to be analyzed and training to be improved.

Workout problems include:

- Transmission errors. These are occasionally troublesome; they can be recognized and corrected.
- Trainer load problems. These are easy to spot; they can be corrected.
- Athlete effort problems—often pacing errors. Downloads are great for recognizing such errors. Correct pacing can lead to training that is more effective.

Standard 3-Month HIT™ Program

Workout Recording Examples

Here are examples of heart-rate, cadence, torque, and power recordings from Standard HIT™ workouts.

Keep in mind that most of the recordings that follow are of elite athletes, experienced athletes; and athletes who have performed stationary trainer workouts for years.

Most of these recordings are therefore from athletes who are able to perform workouts at the upper ranges of protocols and who are able to pace their workouts much better than riders new to interval work.

Standard Workout 1A Recordings

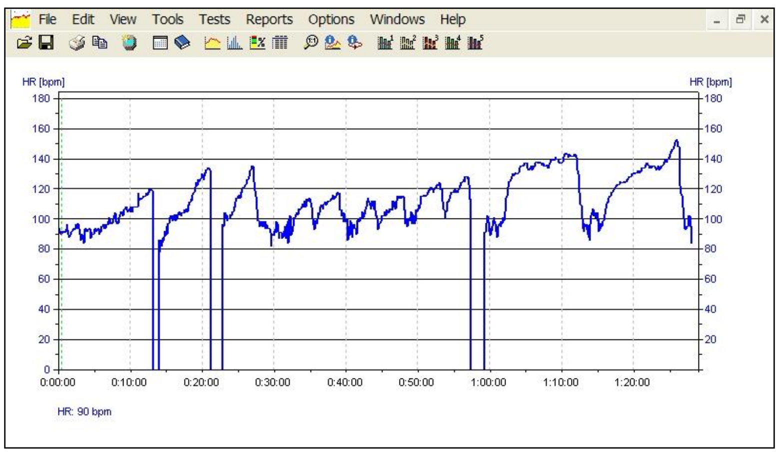


Figure 102. Standard HIT workout 1A. Polar heart-rate download. This athlete's maximum heart rate is 190.

Spin-ups, ILTs, and stand climbing tempo are not aerobically demanding.

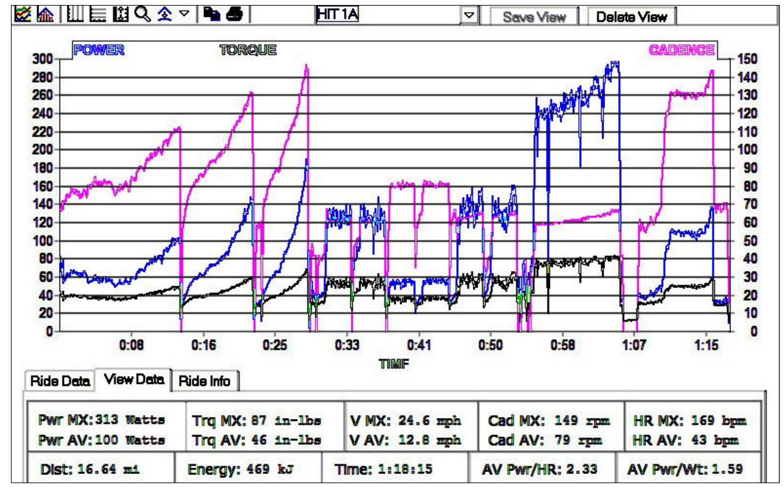


Figure 103. Standard HIT workout 1A. PowerTap download. From the top: Cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

A power meter gives more information than a heart-rate monitor does.

Since trainer resistances vary, energy used for the workout (469 kilojoules) is a better measure of training volume than distance (16.64 miles).

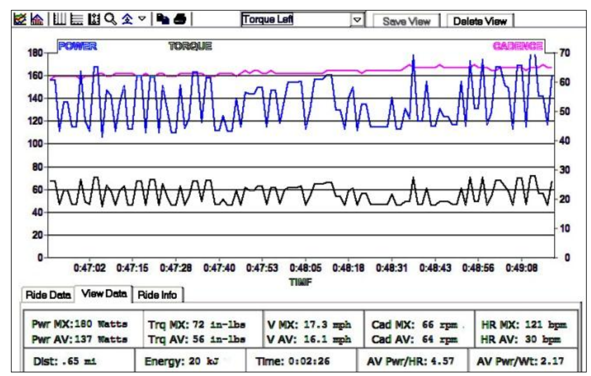


Figure 104. Zoom from above workout: Final left-leg ILT.

60-rpm ILTs are a torque exercise. Here wheel torque averages 56 pound-inches. Using a 55/17 gear, this translates to 181 pound-inches of crank torque. For more on wheel to crank torque, see page 62.

The zigzag pattern is an artifact, due to a computational precession effect.

Standard Workout 1B Recordings

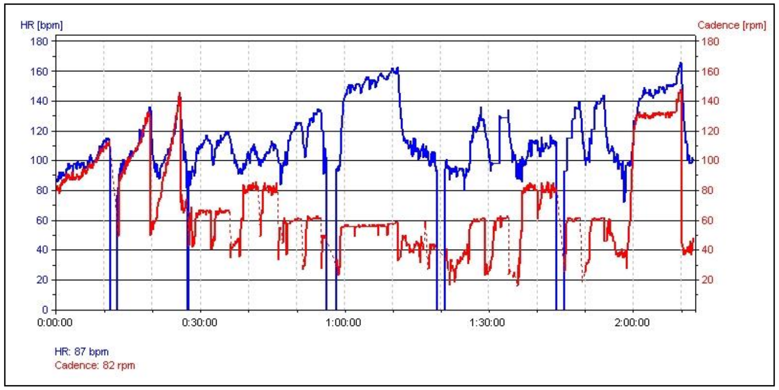


Figure 105. Standard HIT workout 1B. Polar heart rate and cadence download. Similar to previous Figure 102, with cadence added. Heart rate, blue; cadence, red. This athlete's maximum heart rate is 190.

Spin-ups are about neuromuscular fitness (cadence). Choose gears and control trainer settings so that spin-ups are not aerobically demanding.

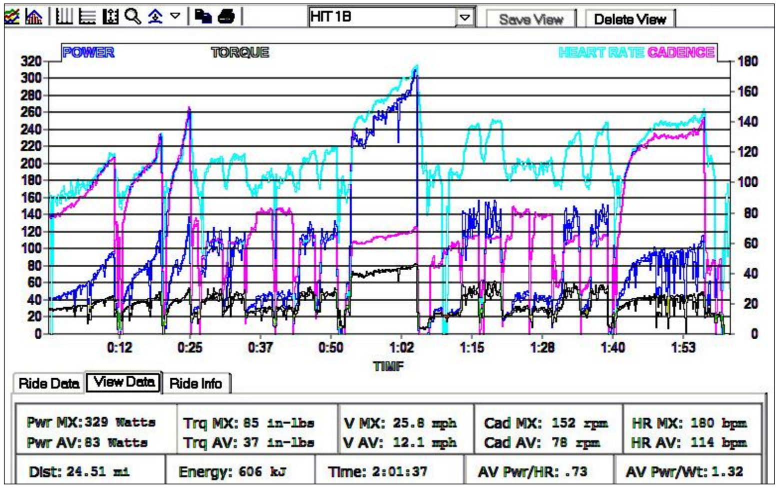


Figure 106. Standard HIT workout 1B. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

A power meter gives more information than a heart-rate monitor does.

Since trainer resistances vary, energy used for the workout (606 kilojoules) is a better measure of training volume than distance (24.51 miles).

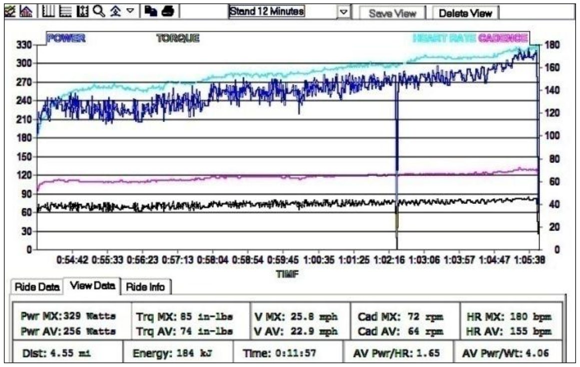


Figure 107. Zoom from above workout: Standing climb, 12 minutes. Note gradual increase in power, torque, heart rate, and cadence.

ZOOM and VIEW DATA allows the program to calculate average power for the interval, 256 watts; and average power-to-weight for the interval, 4.06 watts per kilogram.

Standard Workout 2A Recordings

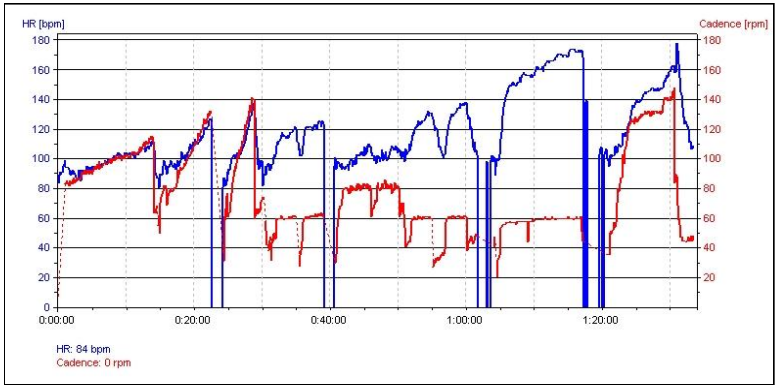


Figure 108. Standard HIT workout 2A. Polar heart rate and cadence download. Heart rate, blue; cadence, red. This athlete's maximum heart rate is 190.

Note control of cadence in spin-ups and ILTs. Note heart rate rises (drifts upward) even though cadence remains constant during stand climbing tempo.

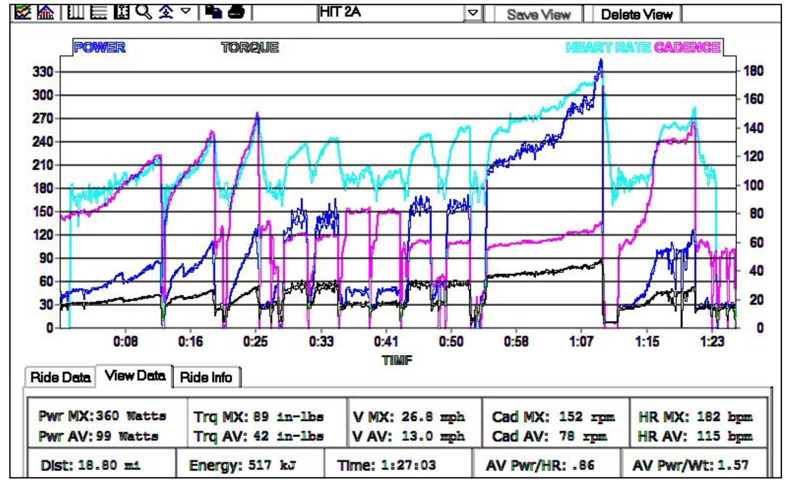


Figure 109. Standard HIT workout 2A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

A power meter gives more information than a heart-rate monitor does.

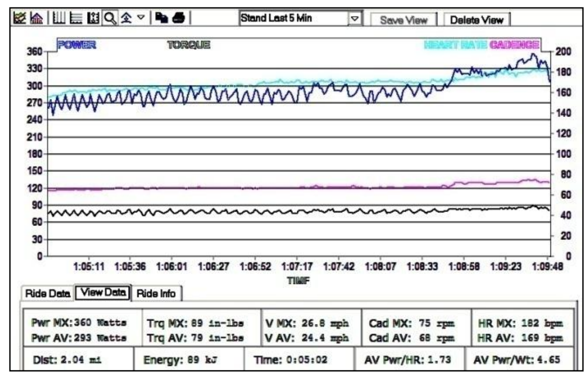


Figure 110. Zoom from above workout: Standing climb, last 5 of 15 minutes.

ZOOM and VIEW DATA allows the program to calculate average power for the last 5 minutes, 293 watts; and average power-to-weight for the interval, 4.65 watts per kilogram.

Standard Workout 2B Recordings

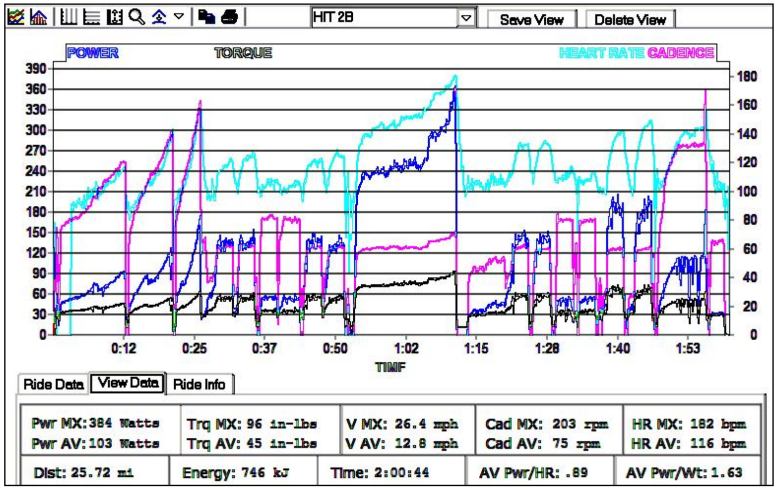


Figure 111. Standard HIT workout 2B. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

This athlete performs the final spin at 130 rpm, higher than nominal cadence.

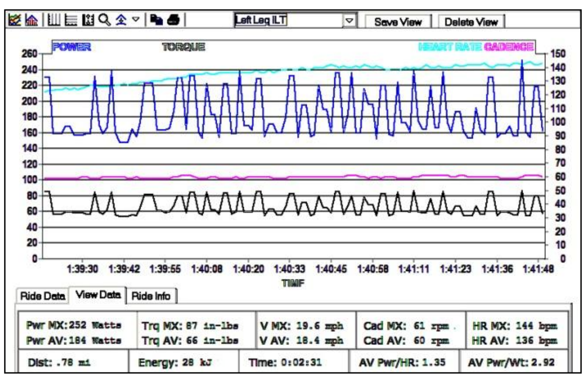


Figure 112. Zoom from above workout: Last left-leg ILT.

Wheel torque averages 66 pound-inches. Using a 55/14 gear, this translates to 260 pound-inches of crank torque. The athlete's torque has increased from the 181 pound-inches of torque in HIT 1A, Figure 104.

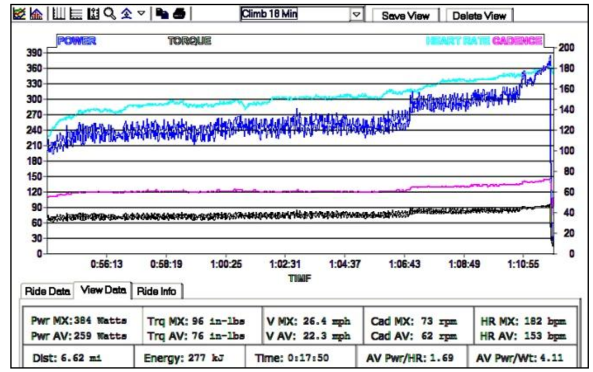


Figure 113. Zoom from above workout: Standing climb, 18 minutes.

ZOOM and VIEW DATA allows the program to calculate average power for the interval, 259 watts; and average power-to-weight for the interval, 4.11 watts per kilogram. The athlete has worked longer and a little harder than in HIT 1B: Power has increased from the 256 watts and 4.06 watts per kilogram in HIT 1B, Figure 107.

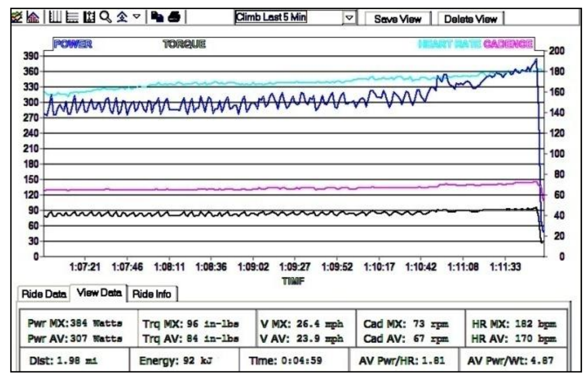


Figure 114. Zoom from above workout: Standing climb, last 5 of 18 minutes.

ZOOM and VIEW DATA allows the program to calculate average power for the last 5 minutes, 307 watts; and average power-to-weight for the interval, 4.87 watts per kilogram. The athlete's power during the last 5 minutes has increased from the 293 watts and 4.65 watts per kilogram in HIT 2A, Figure 110.

Standard Workout 3A Recordings

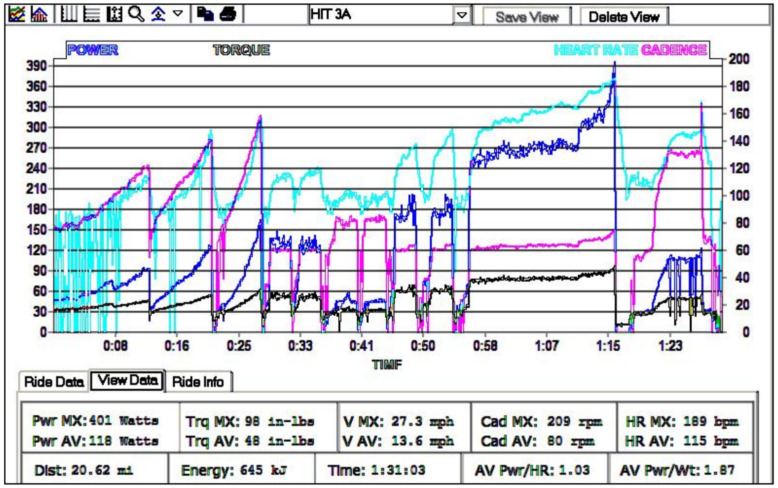


Figure 115. Standard HIT workout 3A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Poor heart-rate strap electrode contact at beginning of workout.

Again, note control of cadence in spin-ups and ILTs. Heart rate rises (drifts upward) relatively more than cadence during stand climbing tempo. This athlete performs the final spin at 130 rpm, higher than nominal cadence.

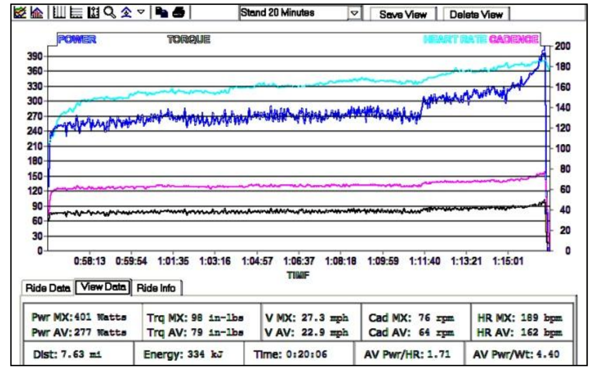


Figure 116. Zoom from above workout: Standing climb, 20 minutes.

Average power for the interval, 277 watts; and average power-to-weight for the interval, 4.40 watts per kilogram. The athlete has worked longer and a little harder than in HIT 1B: Power has increased from the 256 watts and 4.06 watts per kilogram in HIT 1B, Figure 107.

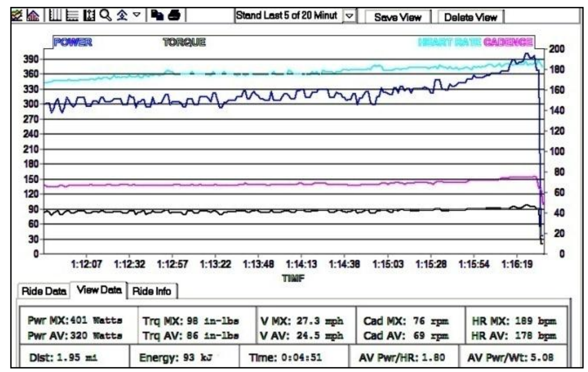


Figure 117. Zoom from above workout: Standing climb, last 5 of 20 minutes.

Average power for the last 5 minutes, 320 watts; and average power-to-weight for the interval, 5.08 watts per kilogram. The athlete's power during the last 5 minutes has increased from the 293 watts and 4.65 watts per kilogram in HIT 2A, Figure 110.

Standard Workout 3B Recordings

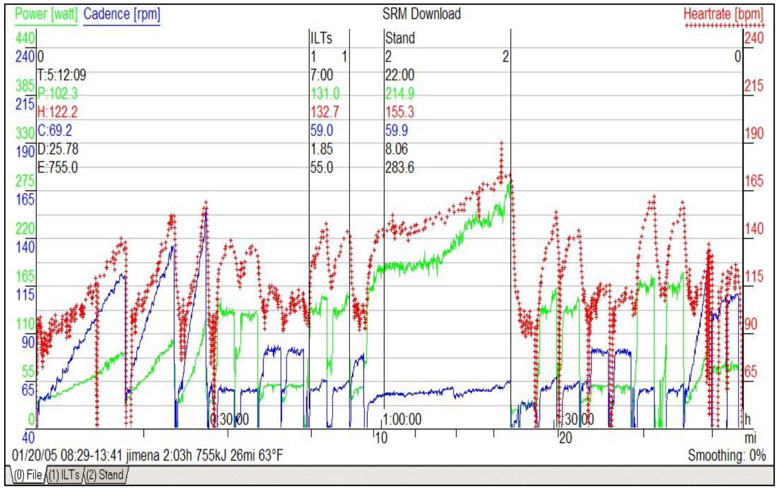


Figure 118. Standard HIT workout 3B. SRM download. Power, green; heart rate, red; and cadence, blue. World-class 33-year-old female mountain-bike rider. This athlete weighs 55 kilograms (122 pounds); maximum heart rate is 195.

Spin-ups to 105 watts or about 2 watts per kilogram. Moderate-gear 60 rpm ILTs to 150 watts or almost 3 watts per kilogram. Stand climbing tempo, last 22 minutes at about 215 watts or 3.9 watts per kilogram.

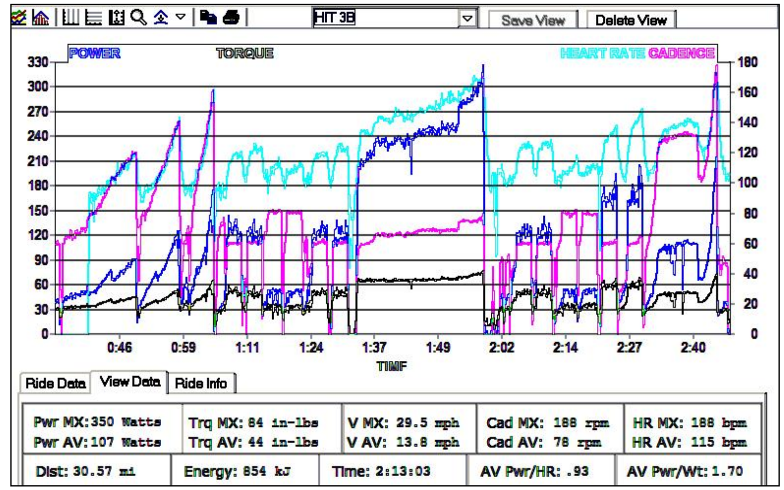


Figure 119. Standard HIT workout 3B. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

This athlete performs the final spin at 130 rpm, higher than nominal cadence, and then participates in *Spin Wars*, a final spin-up increasing cadence 5 rpm every 10 seconds. Detail below.

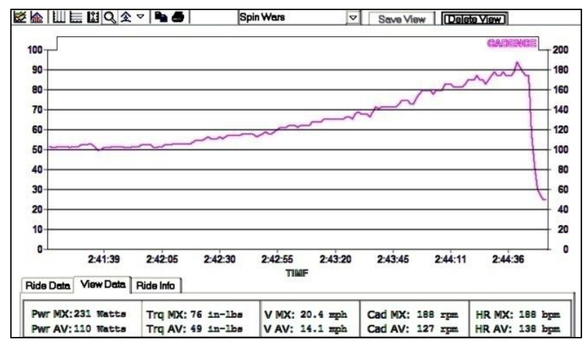


Figure 120. Zoom from above workout: Spin wars. Cadence, pink. Final spin-up increasing cadence 5 rpm every 10 seconds until cadence 180+ rpm.

Standard Workout 4A Recordings

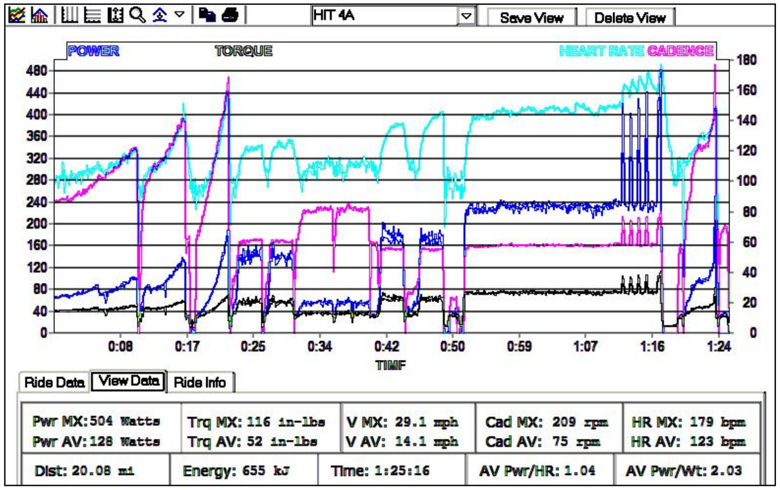


Figure 121. Standard HIT workout 4A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Again, note control of cadence in spin-ups and ILTs. Heart rate rises and falls slightly with position changes during stand climbing tempo. Heart rate rises during standing surges.

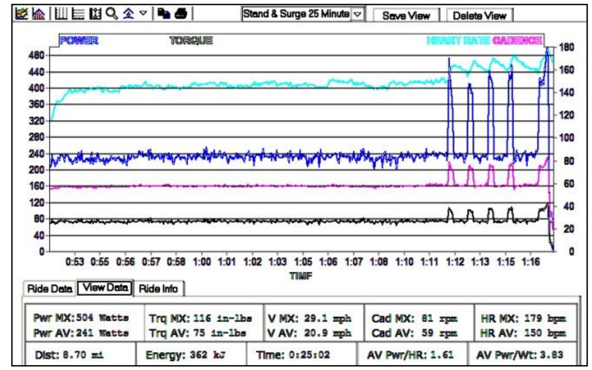


Figure 122. Zoom from above workout: Standing climb, 25 minutes, with 5 surges.

Average power for the interval, 241 watts; and average power-to-weight for the interval, 3.83 watts per kilogram.

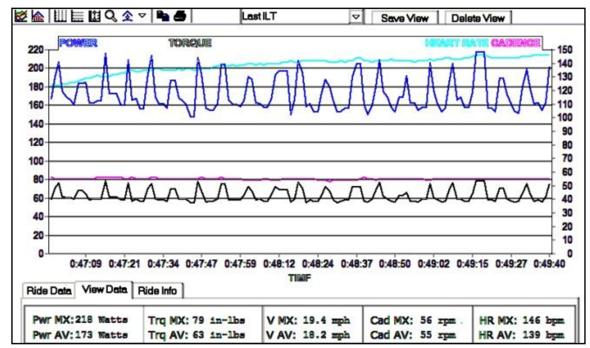


Figure 123. Zoom from above workout: Last left-leg ILT.

Wheel torque averages 63 pound-inches. Using a 55/13 gear, this translates to 266 pound-inches of crank torque. The athlete's torque has increased from the 181 pound-inches of torque in HIT 1A, Figure 104.

Standard Workout 4B Recordings

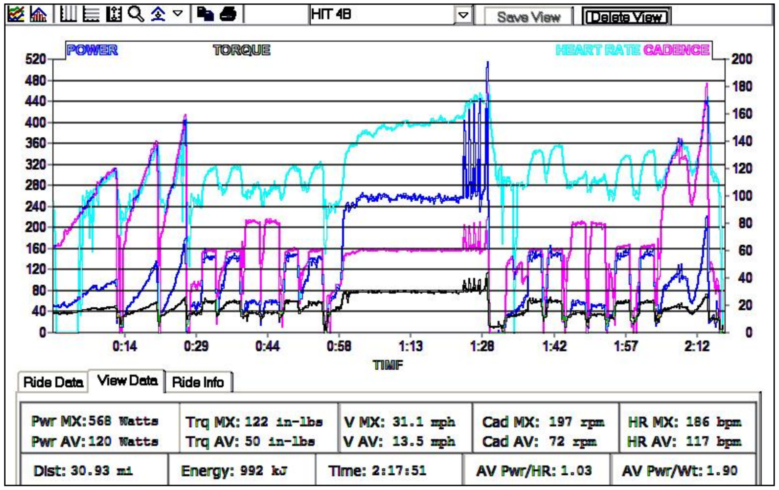


Figure 124. Standard HIT workout 4B. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

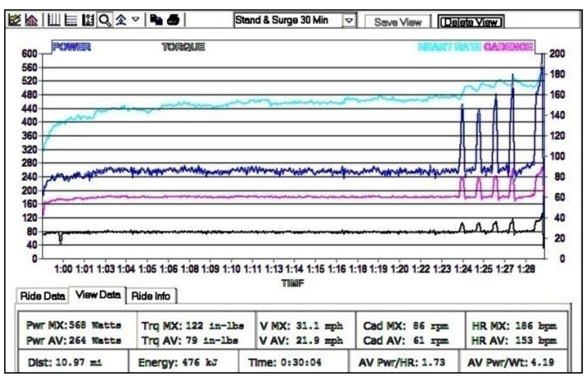


Figure 125. Zoom from above workout: Standing climb, 30 minutes, with 5 surges.

Average power for the interval, 264 watts; and average power-to-weight for the interval, 4.19 watts per kilogram.

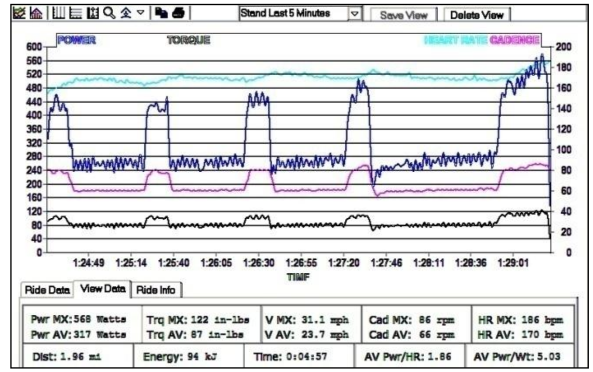


Figure 126. Zoom from above workout: Standing climb, 5 surges, last 5 of 30 minutes.

Average power for the last 5 minutes, 317 watts; and average power-to-weight for the interval, 5.03 watts per kilogram.

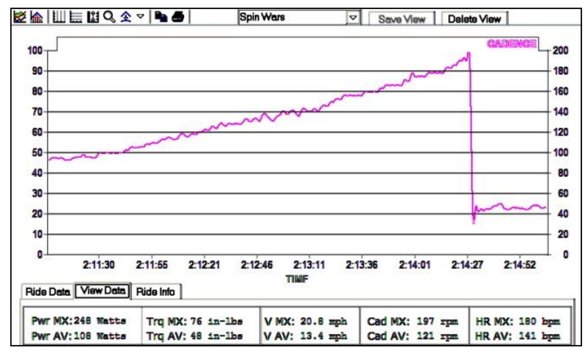


Figure 127. Zoom from above workout: Spin wars. Cadence, pink. Final spin-up increasing cadence 5 rpm every 10 seconds until cadence 195^{+}.

Standard Workout 5A Recordings

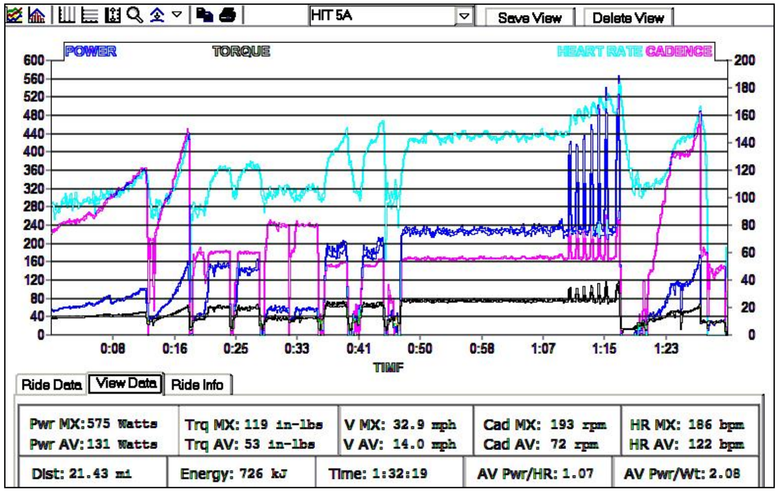


Figure 128. Standard HIT workout 5A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Again, note control of cadence in spin-ups. This athlete performs the final spin at higher than nominal cadence.

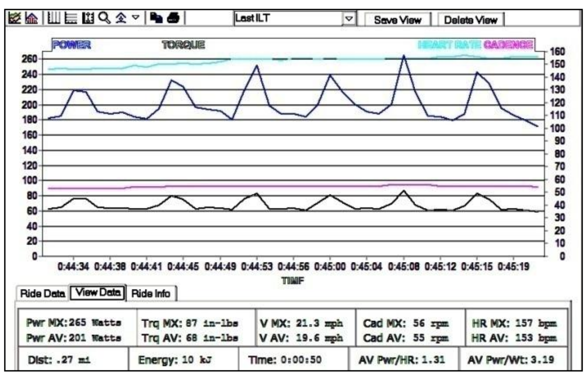


Figure 129. Zoom from above workout: Last left-leg ILT.

Wheel torque averages 68 pound-inches. Using a 55/12 gear, this translates to 311 pound-inches of crank torque. The athlete's torque has increased from the 181 pound-inches of torque in HIT 1A, Figure 104.

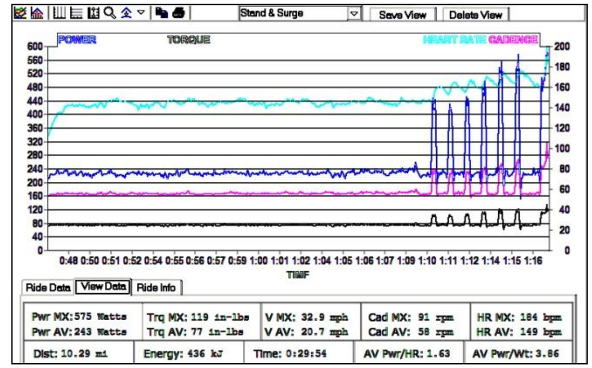


Figure 130. Zoom from above workout: Standing climb, 30 minutes, with 7 surges.

Steady-state baseline power, about 230 watts. Average power, including surges, 243 watts; and average power-to-weight for the interval, 3.86 watts per kilogram.

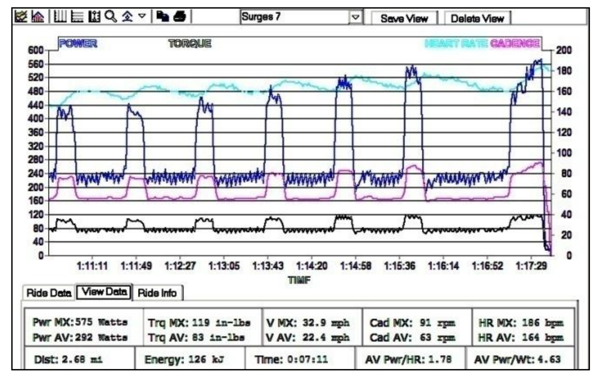


Figure 131. Zoom from above workout: Standing climb, 7 surges.

Average power for the last 7 minutes, 292 watts; and average power-to-weight for the interval, 4.63 watts per kilogram.

Standard Workout 6A Recordings

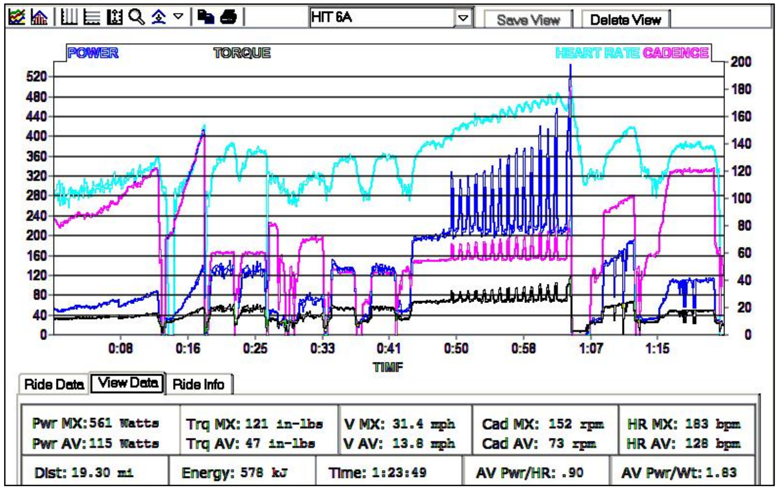


Figure 132. Standard HIT workout 6A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

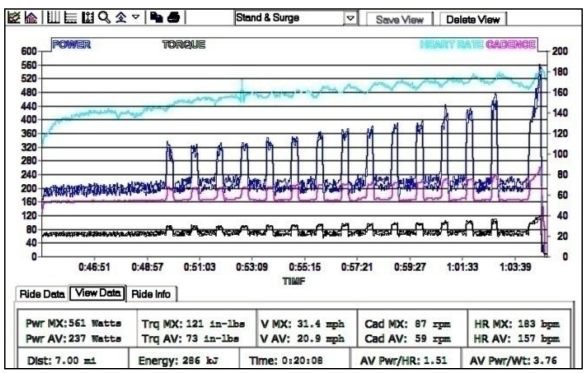


Figure 133. Zoom from above workout: Standing climb, 20 minutes, with 15 surges.

Steady-state baseline power, about 200 watts. Surges to about double baseline power. Average power, including surges, 237 watts; and average power-to-weight for the interval, 3.76 watts per kilogram. Heart rate is 183 bpm or 96% of maximum at the end of the last surge.

Note progressive control of effort in the surges. Note maintenance of baseline power between surges.

Focus and pacing trick: The athlete starts each odd-numbered interval with his left leg and each even-numbered interval with his right leg.

He counts 10 strokes of his first leg, and then 10 strokes of his second leg to fit into 15 seconds for each of the first 4 surges.

He then counts 10 strokes of his first leg and then 11 strokes of his second leg for the next 4 surges (surges 5 through 8).

He then counts 11 stokes of his first leg and 12 strokes of his second leg for the next 4 surges (surges 9 through 12).

He counts 11 strokes of his first leg and 12 strokes of his second leg for surges 13 and 14.

For the last surge, which is for 30-seconds, he counts 11 strokes of his left leg, then 11 strokes of his right leg, and then tries to accelerate through the last 15 seconds of the surge.

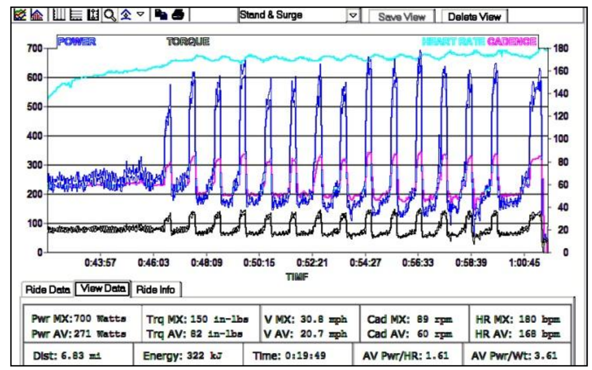


Figure 134. Different athlete than above. Zoom of standing climb, 20 minutes, with 15 surges.

Surges about 2.5 times baseline power. Note lack of progressive control of effort in the surges and erosion of baseline power between surges. This is a different approach to performing the exercise.

Standard Workout 6B Recordings

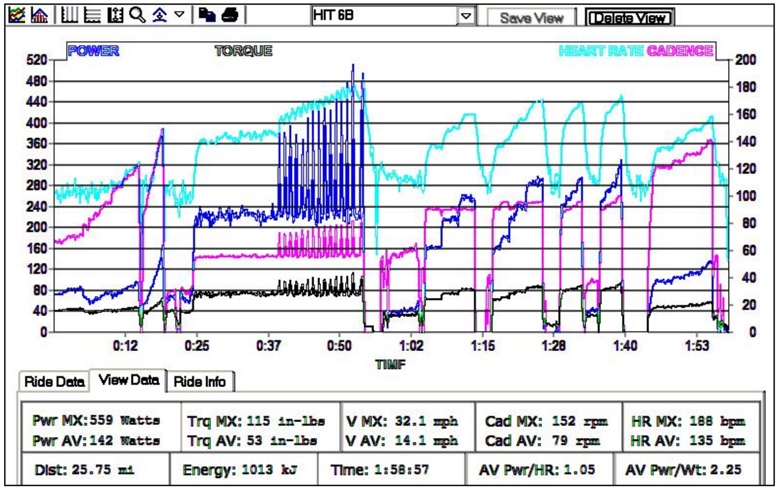


Figure 135. Standard HIT workout 6B. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Spin-Ups: **This rider performs the spin-ups as directed: 50 to 120 rpm; 70 to 150 rpm.**

Stand Climbing Tempo and Standing Surges: **Details on the right.**

9-Minute Progressive Intervals: **Interval ending power about 260 and 290 watts. Interval ending heart rate at 160 and 170 beats per minute, or at about 85% and 90% of maximum heart rate.**

4-Minute Intervals: **Interval ending power at about 295 and 320 watts. Interval ending heart rate at 170 and 173 beats per minute, or at about 90% of maximum heart rate.**

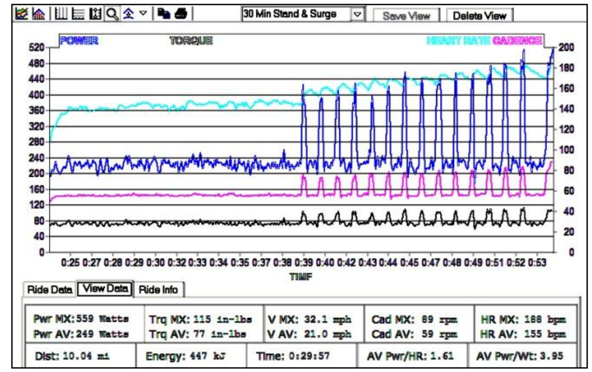


Figure 136. Zoom from above workout: Standing climb, 30 minutes, with 15 surges.

Steady-state baseline power, about 220 watts. Average power, including surges, 249 watts; and average power-to-weight for the interval, 3.95 watts per kilogram.

Again, note progressive control of effort in the surges. Note maintenance of baseline power between surges.

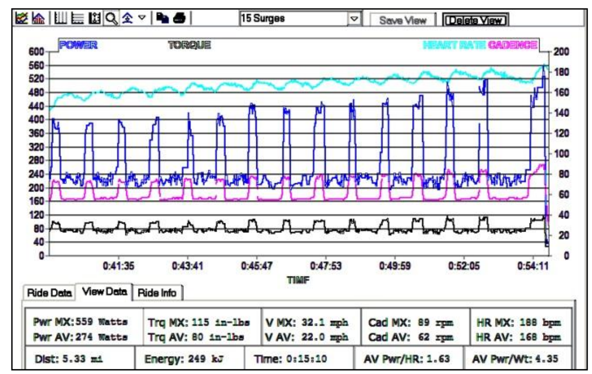


Figure 137. Zoom from above workout: Standing climb, 15 surges.

Surges at 400 to 500 watts, roughly double baseline power. Average power for the last 15 minutes, 274 watts; and average power-to-weight for the interval, 4.35 watts per kilogram. Last surge ending heart rate at 188, or 99% of maximum heart rate.

Standard Workout 7A Recordings

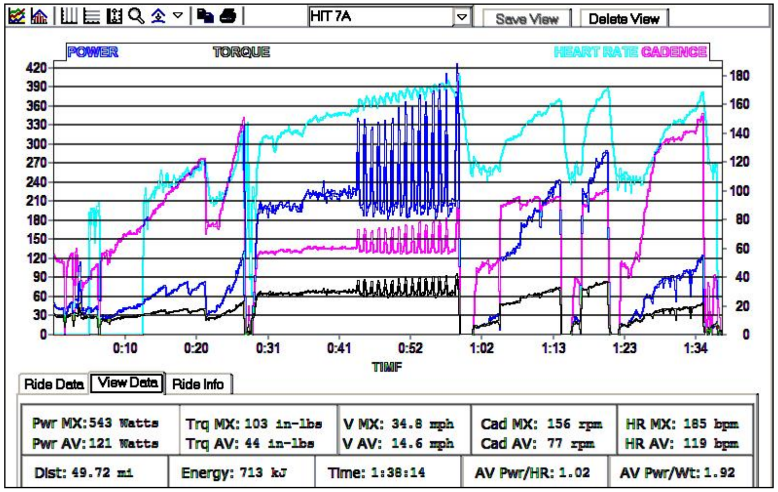


Figure 138. Standard HIT workout 7A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. National-class 53-year-old male road rider. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Spin-Ups: **Details on the right.**

Stand Climbing Tempo and Standing Surges: **Details on the right.**

9-Minute Progressive Intervals: **This exercise is performed in a 39/17, 39/16 and 39/14 at 90 to 95 rpm. Interval ending power about 260 watts. Interval ending heart rate at 165 beats per minute, or at about 85% of maximum heart rate.**

4-Minute Intervals: **Interval ending power at about 290 watts. Interval ending heart rate at 170 beats per minute, or at about 90% of maximum heart rate.**

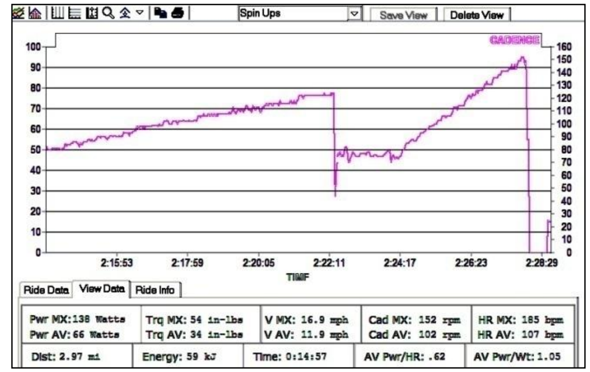


Figure 139. Zoom from above workout: Spin-Ups:

This rider performs the first spin-ups as directed, 50 to 120 rpm; the second from 80 to 150 rpm.

The program draws incorrectly in Figure 138 above: The graph shows the cadence to 180 rpm, the VIEW DATA report shows maximum cadence for the workout at 156 rpm.

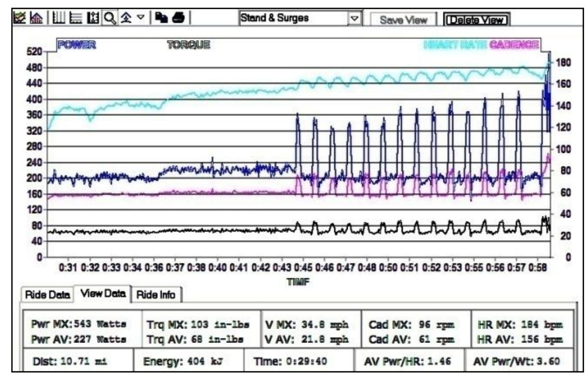


Figure 140. Zoom from above workout: Standing climb, 30 minutes, with 15 surges.

Steady-state baseline power, about 200 watts at 57 rpm the first 7 minutes, about 220 watts at 60 rpm the next 8 minutes. Average power, including surges, 227 watts; and average power-to-weight for the interval, 3.60 watts per kilogram.

Again, note progressive control of effort in the surges. Note maintenance of baseline power, 200 watts, between surges.

Standard Workout 7A Recordings

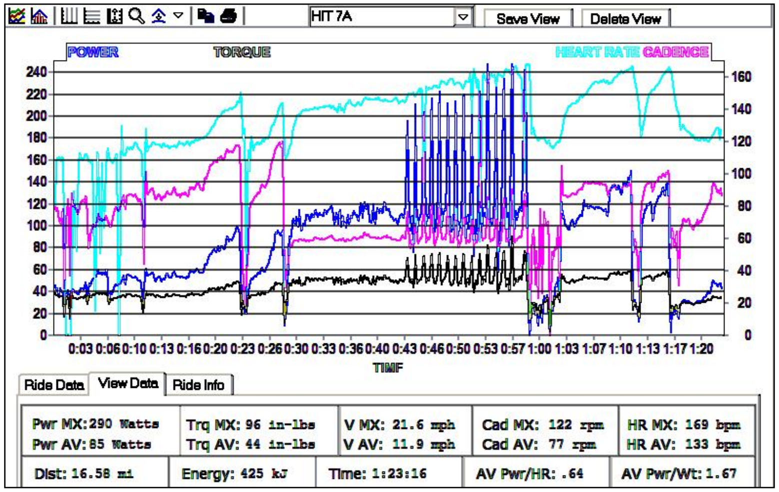


Figure 141. Standard HIT workout 7A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. Strong 55-year-old female recreational rider. This athlete weighs 51 kilograms (112 pounds); maximum heart rate is 182.

Spin-Ups: **This rider performs the spin-ups at a lower higher cadence than suggested: From 60 rpm to 120 rpm and from 80 rpm to 120 rpm.**

Stand Climbing Tempo and Standing Surges: **Steady-state baseline power, about 110 watts, about 2 watts per kilogram. Surges between 200 and 250 watts, 4 to 5 watts per kilogram.**

Again, note progressive control of effort in the surges and maintenance of baseline power between surges.

9-Minute Progressive Intervals: **Interval ending power about 140 watts. Interval ending heart rate at 168 beats per minute, or at about 92% of maximum heart rate.**

4-Minute Intervals: **Interval ending power at about 140 watts. Interval ending heart rate at 168 beats per minute, or at about 92% of maximum heart rate.**

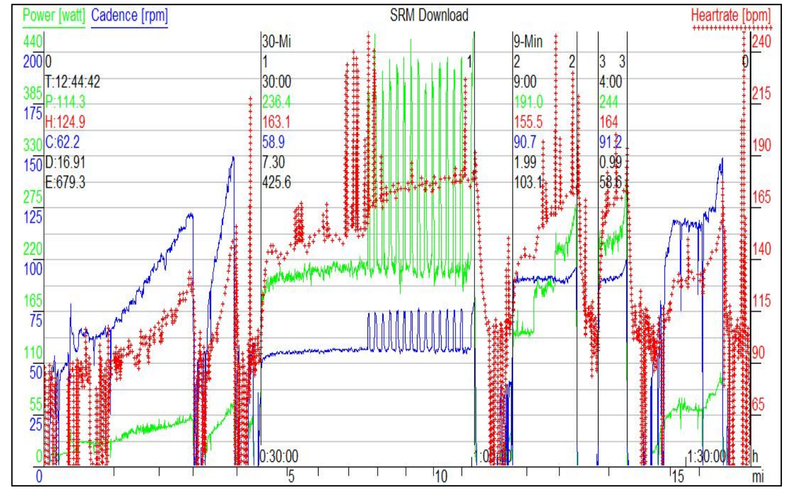


Figure 142. Standard HIT workout 7A. SRM download. Power, green; heart rate, red; and cadence, blue. World-class 33-year-old female mountain-bike rider. This athlete weighs 55 kilograms (122 pounds); maximum heart rate is 195.

Spin-Ups: **This rider performs the spin-ups as suggested: From 60 rpm to 120 rpm and from 80 rpm to 150 rpm.**

Stand Climbing Tempo and Standing Surges: **Steady-state baseline power, about 210 watts, about 3.8 watts per kilogram. Surges between 400 and 450 watts, about 8 watts per kilogram. Average power for the 30 minutes, 236 watts, or 4.3 watts per kilogram.**
Last surge ending heart rate at 181 beats per minute, or at about 93% of maximum heart rate.

9-Minute Progressive Intervals: **Interval ending power about 275 watts. Interval ending heart rate at 176 beats per minute, or at about 90% of maximum heart rate.**

4-Minute Intervals: **Interval ending power at about 275 watts. Interval ending heart rate at 177 beats per minute, or at about 90% of maximum heart rate.**

Standard Workout 7B Recordings

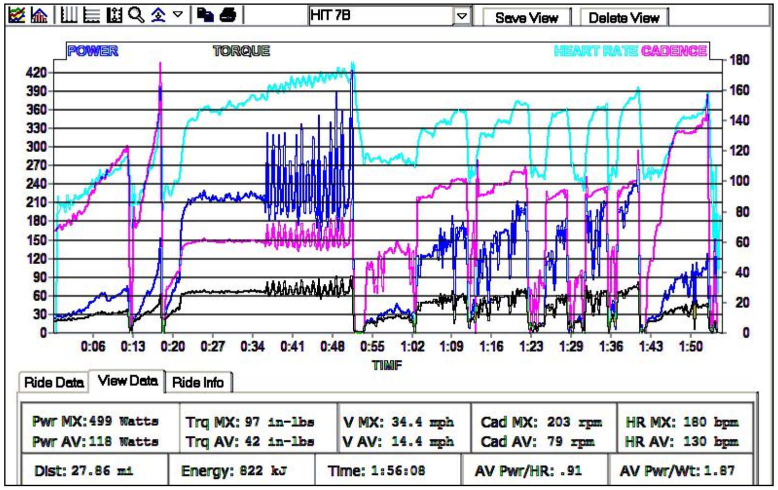


Figure 143. Standard HIT workout 7B. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

The hub batteries are weakening, and dropped torque transmissions are present in the last half of the recording.

Spin-Ups: **This rider performs the spin-ups as directed: 50 to 120 rpm; 70 to 150 rpm. There is a drawing error in the program application, as described on page 174.**

Stand Climbing Tempo and Standing Surges: **Details on the right.**

9-Minute Progressive Intervals: **Interval ending power about 180 and 210 watts. Interval ending heart rate at 145 and 152 beats per minute, or at about 75% and 80% of maximum heart rate. Compare to workout 7A, Figure 138: The athlete is floating this exercise.**

4-Minute Intervals: **Interval ending power at about 180, 200, and 240 watts. Interval ending heart rate at 150, 152, and 160 beats per minute, or at about 85% of maximum heart rate. Again, compare to workout 7A, Figure 138: The athlete is floating this exercise.**

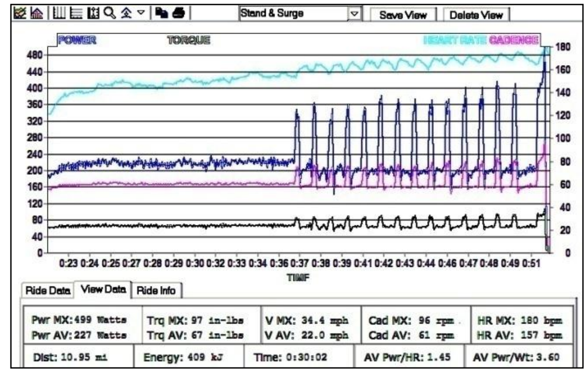


Figure 144. Zoom from above workout: Standing climb, 30 minutes, with 15 surges.

Again, note progressive control of effort in the surges. Note maintenance of lower baseline power, about 200 watts, between surges.

Steady-state baseline power, about 220 watts. Average power, including surges, 227 watts; and average power-to-weight for the interval, 3.60 watts per kilogram.

This workout is considerably harder than earlier short steady-state stand without surges, and average power is lower. For example, compare to workout 3A, Figure 116, where average power for a 20-minute steady stand was 277 watts and average power-to-weight for the interval was 4.40 watts per kilogram.

Standard Workout 8A Recordings

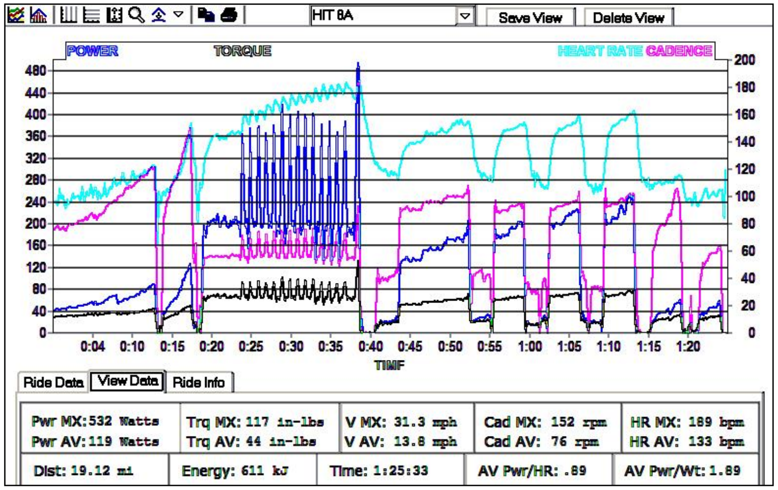


Figure 145. Standard HIT workout 8A. PowerTap download. From the top: Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Spin-Ups: **This rider performs the spin-ups 80 to 120 rpm; 80 to 150 rpm.**

Stand Climbing Tempo and Standing Surges: **Maintenance of baseline power, about 200 watts, between surges. Most surges to roughly double baseline—400 watts. Heart rate is 189 beats per minute or 99% of maximum at the end of the surges, higher than the suggested 90%.**

9-Minute Progressive Intervals: **Interval ending power about 200 watts. Interval ending heart rate at 155 beats per minute, or at about 82% of maximum heart rate. Compare to workout 7A, Figure 138: The athlete is floating this exercise.**

4-Minute Intervals: **Interval ending power at about 200, 220, and 250 watts. Interval ending heart rate at 155, 158, and 163 beats per minute, or at about 82%, 83%, and 86% of maximum heart rate. Again, compare to workout 7A, Figure 138: The athlete is floating this exercise, but less so than in workout 7B, Figure 143.**

Final Spin: **Is not performed--the athlete had cramps.**

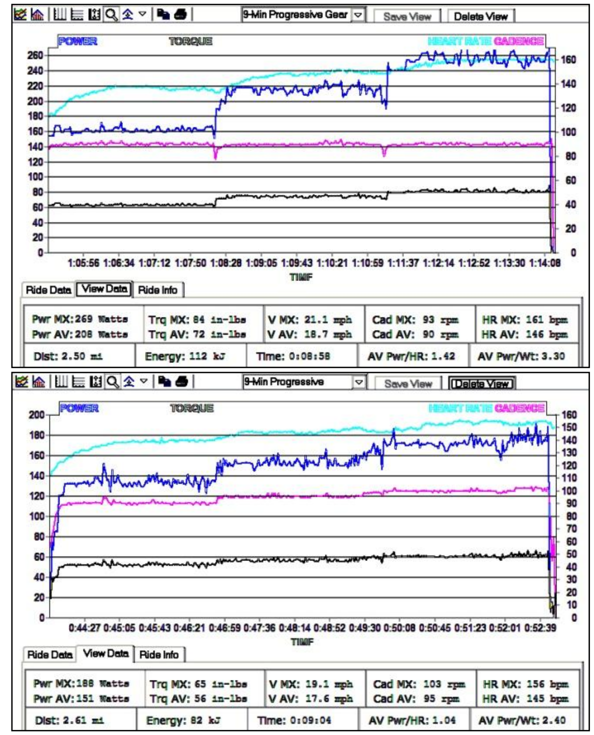


Figure 146. Different approaches to 9-minute progressive intervals. PowerTap downloads. Power, blue; heart rate, turquoise; cadence, pink; and torque, black.

Top: Zoom from Standard HIT workout 6A, Figure 132. Increasing gear every three minutes, cadence constant at 90 rpm.

Bottom: Zoom from HIT 8A, Figure 145, at left. Gear constant, increasing cadence 5 rpm every three minutes.

Standard Workout 8B Recordings

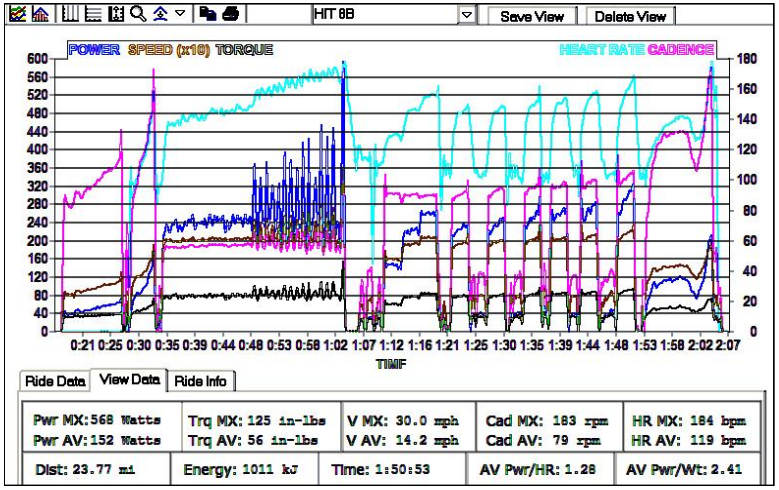


Figure 147. Standard HIT workout 8B. PowerTap download. Heart rate, turquoise; cadence, pink; speed, brown; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Spin-Ups: **This rider performs the spin-ups as directed: 50 to 120 rpm; 70 to 150 rpm. There is a drawing error in the program application, as described on page 174.**

Stand Climbing Tempo and Standing Surges: **Details on the right.**

9-Minute Progressive Intervals: **Interval ending power about 265 watts. Interval ending heart rate at 160 beats per minute, or at about 85% of maximum heart rate.**

4-Minute Intervals: **Six intervals, ending power between 240 and 320 watts. Interval ending heart rates between 150 and 165 beats per minute, or at about 87% of maximum heart rate for the last.**

The athlete is adapting to the six intervals, somewhat floating, after a hard 30-minute stand and surge.

Read more about 3- and 4-minute intervals in *Aerobic Training* and *3-to 5-Minute (VO2) Intervals* on page 113 and page 115.

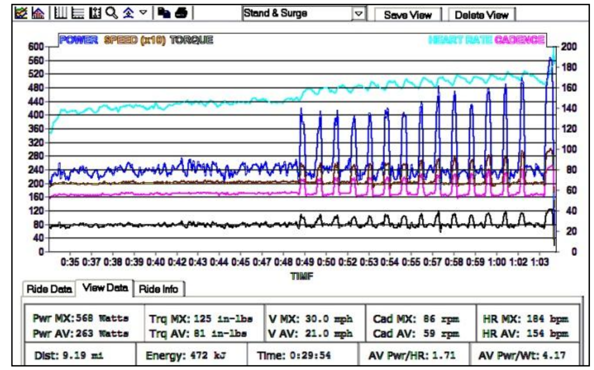


Figure 148. Zoom from above workout: Standing climb, 30 minutes, with 15 surges.

Steady-state baseline power, about 240 watts. Average power, including surges, 263 watts; and average power-to-weight for the interval, 4.17 watts per kilogram.

The athlete has improved performance from the average power of 248 watts, and average power-to-weight for the interval of 3.94 watts per kilogram in Standard HIT 6B Figure 136.

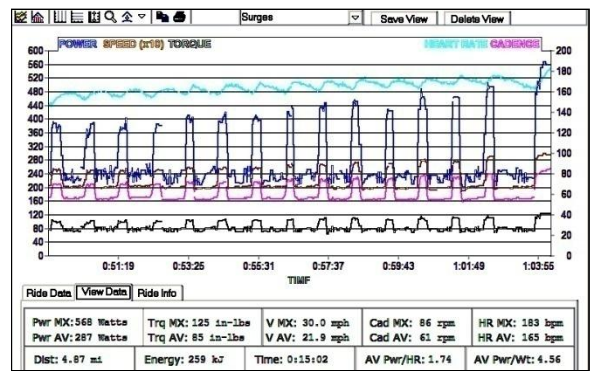


Figure 149. Zoom from above workout: Standing climb, 15 surges.

Surges at 400 to 500 watts, roughly double baseline power. Average power for the last 15 minutes, 287 watts; and average power-to-weight for the interval, 4.56 watts per kilogram. Last surge ending heart rate at 183, or 96% of maximum heart rate. Again, the athlete has improved performance from Standard HIT 6B Figure 137.

The athlete has improved performance from the average power of 275 watts, and average power-to-weight for the interval of 4.37 watts per kilogram in Standard HIT 6B Figure 136.

Standard Workout 9A Recording

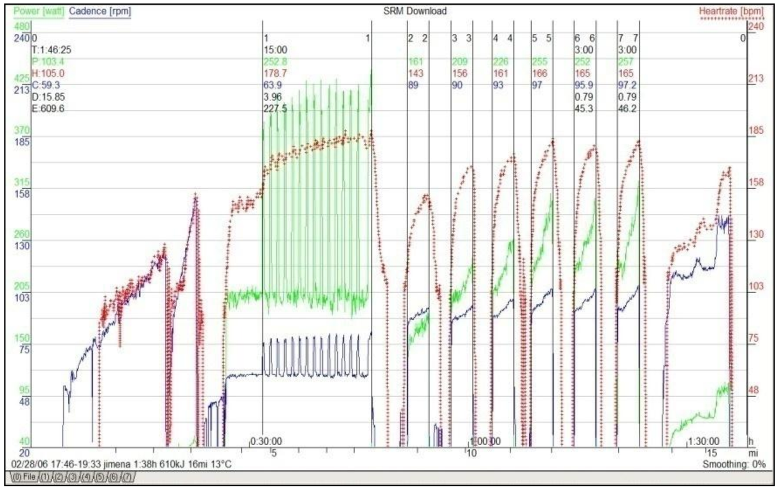


Figure 150. Standard HIT workout 9A. SRM download. Power, green; heart rate, red; and cadence, blue. World-class 33-year-old female mountain-bike rider. This athlete weighs 55 kilograms (122 pounds); maximum heart rate is 195.

The athlete works hard; the athlete will work harder in Standard HIT workout 9B, Figure 151, at right.

***Spin-Ups:* This rider performs the spin-ups as suggested: From 60 rpm to 120 rpm and from 80 rpm to 150 rpm.**

***Stand Climbing Tempo and Standing Surges:* Steady-state baseline power, about 200 watts, about 3.6 watts per kilogram. Surges between 400 and 430 watts, about 7.6 watts per kilogram. Average power for the 15 minutes of surges, 253 watts, or 4.6 watts per kilogram.**

Last surge ending heart rate at 189 beats per minute, or at about 97% of maximum heart rate.

***3-Minute Intervals:* Six progressive 3-minute intervals. Interval ending power from 190 to 315 watts. Interval average power from 161 to 257 watts. Interval ending heart rate at 182 beats per minute, or at about 92% of maximum heart rate.**

Standard Workout 9B Recording

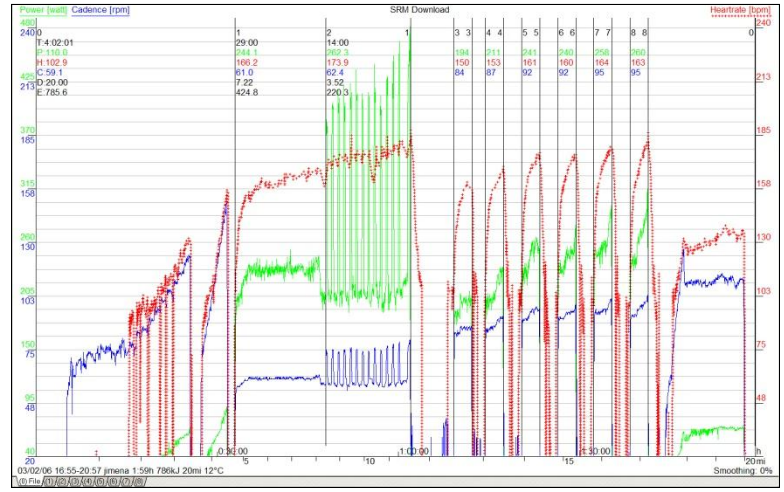


Figure 151. Standard HIT workout 9B. SRM download. Power, green; heart rate, red; and cadence, blue. World-class 33-year-old female mountain-bike rider. This athlete weighs 55 kilograms (122 pounds); maximum heart rate is 195.

Same athlete as in Standard HIT workout 9A, Figure 150, at left. Athlete is working harder.

***Spin-Ups:* This rider performs the spin-ups as suggested: From 60 rpm to 120 rpm and from 80 rpm to 150 rpm.**

***Stand Climbing Tempo and Standing Surges:* Steady-state baseline power, about 240 watts, about 4.4 watts per kilogram. Workout error: Only 14 surges performed. Surges between 400 and 450 watts, about 7.7 watts per kilogram. Average power for the 29 minutes of standing, 244 watts, or 4.4 watts per kilogram. Average power for the 15 minutes of surges, 262 watts, or 4.8 watts per kilogram.**

Last surge ending heart rate at 184 beats per minute, or at about 94% of maximum heart rate.

***3-Minute Intervals:* Six progressive 3-minute intervals. Interval ending power from 190 to 315 watts. Interval average power from 194 to 260 watts. Interval ending heart rate at 183 beats per minute, or at about 94% of maximum heart rate.**

Standard Workout 10A Recordings

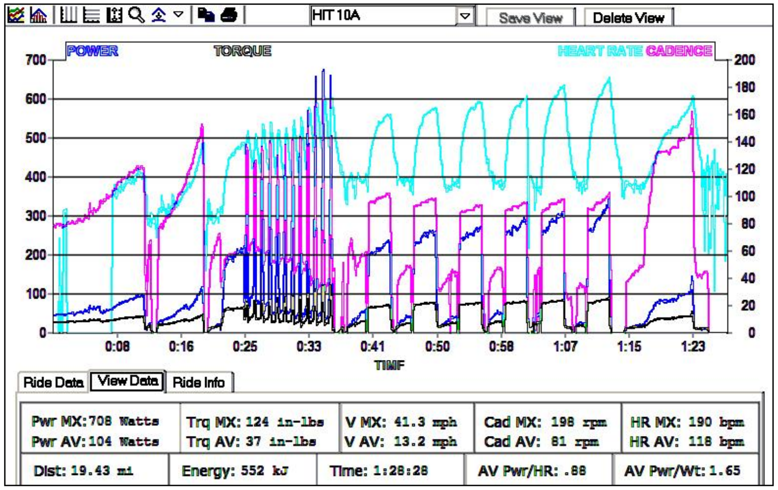


Figure 152. Standard HIT workout 10A. PowerTap download. Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Spin-Ups: **This rider performs the spin-ups as directed: 50 to 120 rpm; 70 to 150 rpm.**

Stand and 12: Sprints **Details on the right.**

3-Minute Intervals: **Six well-paced intervals, ending power between 240 and 350 watts. Interval ending heart rates between 160 and 190 beats per minute, or at about 100% of maximum heart rate for the last.**

The athlete is now performing six intervals at higher heart rates and power outputs than in Standard HIT 8B shown in Figure 147 on page 196.

Read more about 3- and 4-minute intervals in *Aerobic Training* and *3-to 5-Minute (VO2) Intervals* on page 113 and page 115.

Final Spin: **This rider performs the spin at a high cadence: 130 to 150 rpm.**

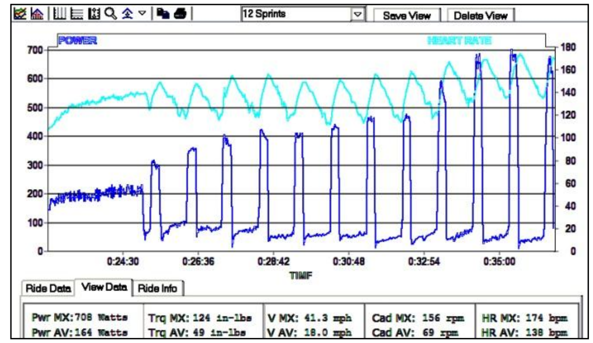


Figure 153. Zoom from above workout: Twelve 15-second sprints. Power, blue; heart rate, turquoise.

Pacing sprints. Each sprint is performed at a higher power level—from 300 to 700 watts or to about 11 watts per kilogram.

Heart rate rises with each sprint. Highest heart rate is 174, or 92% of maximum. Although power outputs are to anaerobic levels, 45-second recoveries do not necessarily result in anaerobic heart rates.

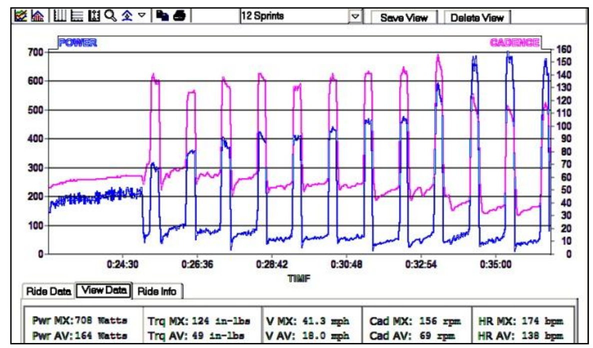


Figure 154. Zoom from above workout: Twelve 15-second sprints. Power, blue; cadence, pink.

With a cadence over 140 and relatively modest power output after the first sprint, the athlete shifts to a harder gear. With cadence over 150, the athlete shifts again after the ninth sprint.

Standard Workout 10B Recording

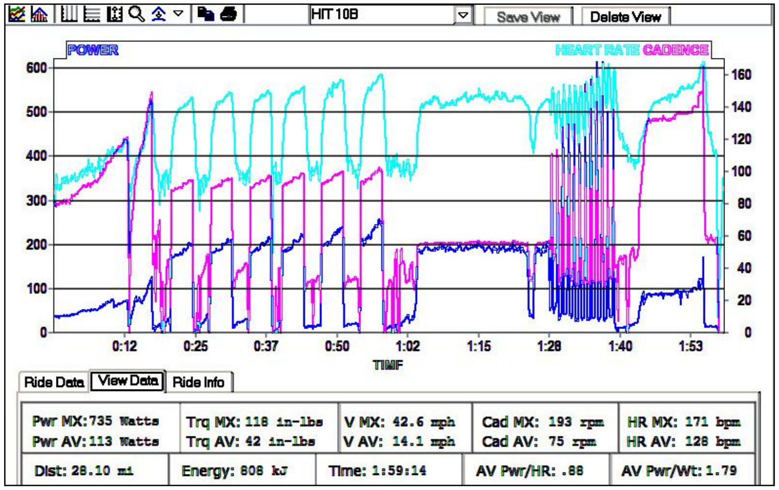


Figure 155. Standard HIT workout 10B. PowerTap download. Heart rate, turquoise; cadence, pink; and power, blue. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

Spin-Ups: **This rider performs the spin-ups as directed: 50 to 120 rpm; 70 to 150 rpm.**

4-Minute Intervals: **Six well-paced intervals, ending power between 200 and 250 watts. Interval ending heart rates between 146 and 160 beats per minute, or at about 84% of maximum heart rate for the last.**

The athlete is floating the exercise in comparison to the work performed in Standard HIT 10A shown in Figure 152 on page 198.

Floating intervals in this way may have value in terms of (1) adapting to interval work and (2) increasing overall training volume. Such work will not maximally train the aerobic system.

Standing Climbing Tempo: **20 minutes of moderate aerobic work. Power at 200 watts. Heart rate at 145 beats per minute, or at about 75% of maximum heart rate.**

Stand and 12 Sprints: **Pacing sprints. Each sprint is performed at a higher power level—from 400 to 700 watts or to about 11 watts per kilogram.**

Heart rate rises with each sprint. Highest heart rate is 169, or 89% of maximum. Although power outputs are to anaerobic levels, 45-second recoveries do not necessarily result in anaerobic heart rates.

Final Spin: **This rider performs the spin at a high cadence: 130 to 150 rpm.**

Standard Workout 12A Recordings

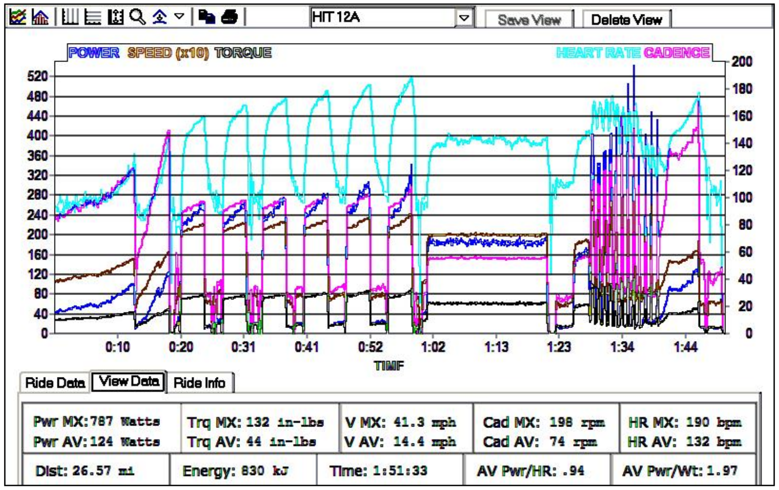


Figure 156. Standard HIT workout 12A. PowerTap download. Heart rate, turquoise; cadence, pink; power, blue; speed, brown, and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

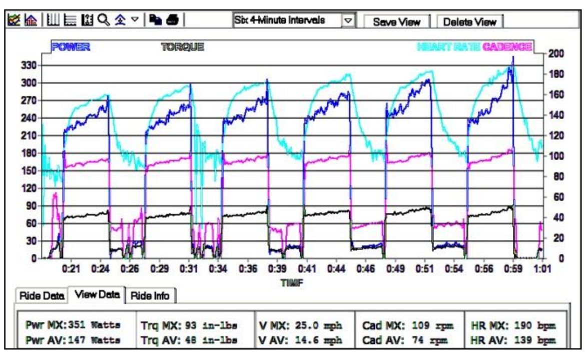


Figure 157. Zoom from above workout. Six 4-minute intervals.

Interval ending power at about 260, 265, 275, 280, 300, and 350 watts. Interval ending heart rate at 160, 167, 172, 179, 184 and 190 beats per minute, or at about 84%, 88%, 91%, 94%, 97%, and 100% of maximum heart rate.

Compare to workout 7A and workout 7B, Figure 138 and Figure 143: The athlete producing more power and working harder.

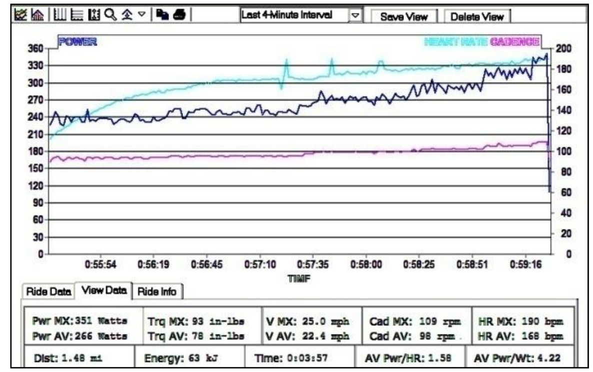


Figure 158. Zoom from above workout. Last 4-minute interval.

Interval ending power at 351 watts. Interval ending heart rate at 190 beats per minute, or at about 100% of maximum heart rate.

Interval average power at 266 watts or 4.22 watts per kilogram.

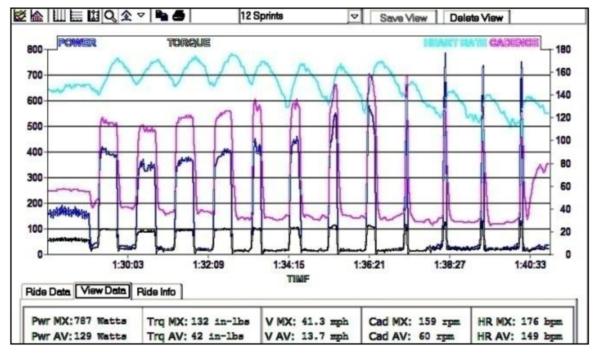


Figure 159. Zoom from above workout. Twelve sprints. Four 30-second, four 15-second, and four 5-second sprints.

This figure shows that the sprints were well-paced, unlike the overview in Figure 156. There is a drawing error in the program application, as described on page 174.

The 30-second sprints are aerobic/anaerobic and associated with relatively high heart rates. As efforts become shorter and recoveries longer, heart rates fall.

Power fell after the first 30-second interval. With a cadence of only 110 rpm per minute, the athlete shifter one cog to a harder gear. Cadence and power picked up.

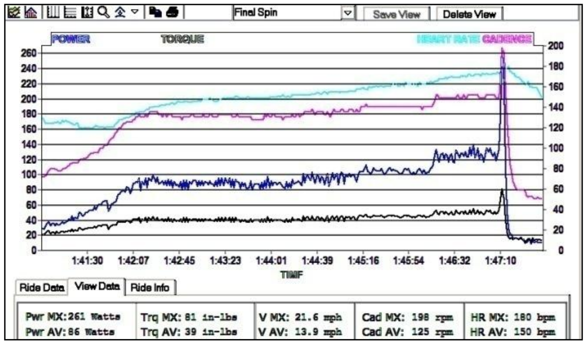


Figure 160. Zoom from above workout. Final spin.

Steady spin from 130 to 150 rpm for five minutes, with a final kick to almost 200 rpm.

Standard Workout 12B Recordings

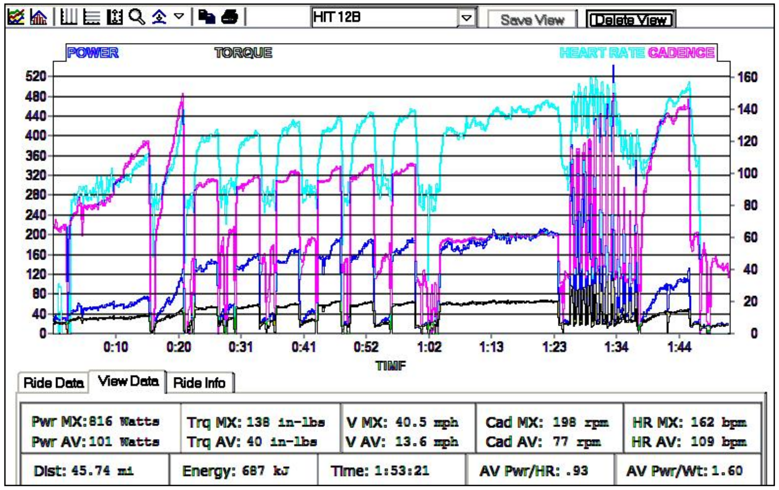


Figure 161. Standard HIT workout 12B. PowerTap download. Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

The six 4-minute intervals are floated: power and heart rate is much lower than in Standard HIT workout 12A, Figure 156, on page 200.

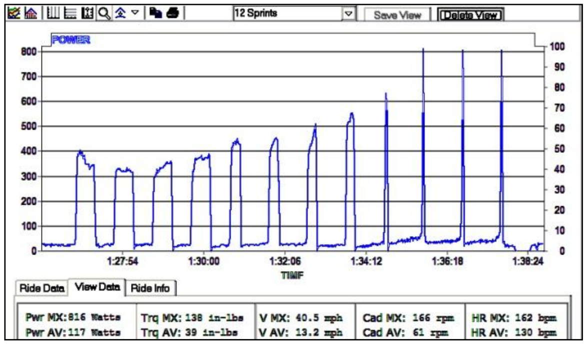


Figure 162. Zoom from above workout. 12 sprints.

There is a drawing error in the program application, as described on page 174. The sprints are well-paced, unlike their appearance Figure 161 above.

30-Second Intervals **average about 370 watts,**

15-Second Intervals **average about 500 watts; and**

5-Second Intervals **average about 800 watts for the last three.**

Periodizing the HIT™ Program

There are many ways to incorporate high-intensity training within the framework of weekly, monthly, seasonal, or annual programs. Below you'll see how fast recreational riders might incorporate a HIT™ program into a seasonal training plan and how racers might incorporate a HIT™ program into an annual plan.

In general, formal high-intensity training programs of several months' duration, such as the 13-week high-intensity program outlined above, should be performed only one time during the first few years of riding. As riders mature, up to 26 weeks of HIT, split into segments of up to 13 weeks, may be attempted annually. Such a volume of intensity training is generally too much even for elite racers, whose racing season adds to the burden of training and risks overtraining.

Where outside riding is problematic due to poor weather, darkness, or limited riding time, the structure provided by HIT-type workouts can provide a framework for year-round stationary training. However true high-intensity efforts should be limited.

For a Fast Century

Most century riders should incorporate high-intensity training only after having already built up endurance and successfully completed a century.

The 18-week program outlined in Table 31, based on the 13-week HIT™ program outlined above, assumes a fitness base of at least 2,000 miles over 4 months of regular riding, and several weeks of 200^{+} miles.

If your fitness base is less, higher intensity training may be incorporated into your training, but the intensity of the 13-week HIT™ program outlined above should be reduced as suggested on page 148.

Mileage credit for two hours of stationary work is 30 to 40 miles. The lower part of the range is for *most* riders; the upper part of the range is for racers.

Total weekly mileage for recreational riders will be in the lower range. Racers may train in the upper range.

Do not forget to consider the big picture: a fast century also demands bicycle handling skills, a sport nutrition strategy, and pacing. Train at least some weeks with double the century climbing volume: If the century has 5,000 feet of climbing, build up and climb 10,000 feet per week several times.

Week	M (Miles)	T (Miles)	W (Miles)	T (Miles)	F (Miles)	S (Miles)	S (Miles)	Total (Miles)
Intensity	*Easy*	*Hard if HIT*	*Easy*	*Hard if HIT*	*Easy*	*Med*	*Easy*	
1	0-25	30	20-50	30	0-25	50	25	155-255
2	0-25	30	20-50	30	0-25	50	25	155-255
3	0-25	30	20-50	30	0-25	60	30	170-270
4	0-25	HIT-1A	20-50	HIT-1B	0-25	60	30	170-270
5	0-25	HIT-2A	20-50	HIT-2B	0-25	60	30	170-270
6	0-25	HIT-3A	20-50	HIT-3B	0-25	70	35	185-285
7	0-25	HIT-4A	20-50	HIT-4B	0-25	70	35	185-285
8	0-25	HIT-5A	20-50	HIT-5B	0-25	70	35	185-285
9	0-25	HIT-6A	20-50	HIT-6B	0-25	80	40	200-300
10	0-25	HIT-7A	20-50	HIT-7B	0-25	80	40	200-300
11	0-25	HIT-8A	20-50	HIT-8B	0-25	80	40	200-300
12	0-25	HIT-9A	20-50	HIT-9B	0-25	90	45	215-315
13	0-25	HIT-10A	20-50	HIT-10B	0-25	90	45	215-315
14	0-25	HIT-11A	20-50	HIT-11B	0-25	90	45	215-315
15	0-25	HIT-12A	20-50	HIT-12B	0-25	100	50	230-330
16	0-25	HIT-13A	20-50	HIT-13B	0-25	100	50	230-330
17	0-25	30	20-50	30	0-25	90	40	210-310
18	0-25	30	20-50	0-25	0-25	10-25	100	160-280

Table 31. 13-week HIT™ incorporated into an 18-week century training program. HIT-*x* refers to the workouts beginning on page 153.

For a Competitive Racer

Table 32 shows one possible annual training approach for a regionally competitive Cat 1-3 amateur racer or a national-level woman or young masters (age 30 to 45) road racer.

Where a daily mileage range is given, more is not necessarily better or desirable. Most riders will be at the lower, not upper, daily mileage range.

The program assumes a climate conducive to year-round bicycle training—such as found in the southern and southwestern United States.

Essential elements of this annual plan include:

January through March

- Standard HIT™ program, twice a week, pre racing season
- Endurance riding three times a week

April and May

- Race type group training twice a week
- Weekend racing (generally 4-6 racing days per month)

June

- Event-specific rapid 9-week HIT™ program before target competition in August (for example, a championship event). A rapid HIT™ program for a road racer is given below, starting on page 204.
- Weekend racing (generally 4-6 racing days)

July and August

- Target event
- General race training and racing

September and October

- Recovery months—reduced volume and intensity of training

November and December

- Endurance base training

Month	M (Miles)	T (Miles)	W (Miles)	T (Miles)	F (Miles)	S (Miles)	S (Miles)
Intensity	*Easy*	*Hard: Jan to Aug*	*Easy to Mod*	*Hard: Jan to Aug*	*Easy*	*Med to Hard*	*Med to Hard*
Jan	0-50	HIT	50-100	HIT	0-50	50-100	50-100
Feb	0-50	HIT	50-100	HIT	0-50	50-100	50-100
Mar	0-50	HIT	50-100	HIT	0-50	Race	50-100
Apr	0-50	TT Train	50-100	Crit Train	0-50	Race	50-100
May	0-50	TT Train	50-100	Crit Train	0-50	Race	Race
Jun	0-50	HIT	50-100	HIT	0-50	Race	50-100
Jul	0-50	TT Train	50-100	Crit Train	0-50	Race	Race
Aug	0-50	TT Train	50-100	Crit Train	0-50	Race	50-100
Sep	0-50	25-50	0-100	25-50	0-50	0-100	0-100
Oct	0-50	25-50	25-100	25-50	0-50	25-100	25-100
Nov	0-50	25-50	50-100	25-50	0-50	50-100	50-100
Dec	0-50	25-50	50-100	25-50	0-50	50-100	50-100

Table 32. 13-weeks of HIT™ incorporated into 3 months pre-race training and 4 weeks of HIT™ incorporated into target-event race training. TT Train and Crit Train are time trial and criterium training workouts respectively.

Cross-Country Mountain Biker

Modify the schedule as follows:

- Incorporate skills training October through March.
- Substitute dirt workouts for time trial and/or criterium training Tuesdays and/or Thursdays during the racing season.
- Ride one day of each weekend on dirt.

Part 5:
Rapid (5 to 9 Week) HIT™ Programs

9-Week Rapid HIT™ Program

The following is a 2-month (9-week) rapid high-intensity training program. The program assumes at least a 6-month, 6,000-mile fitness base of endurance riding. Completion of a pre-season standard 3-month (13-week) program and two-months of general racing is desirable.

I have used similar programs to help bring dozens of riders to a racing peak before major events, such as National Championships.

General information about such programs, stationary training, examples of workouts with heart rate and cadence analysis is found in the previous section, Part 4, Standard HIT™ Program.

A description of workout protocols for the rapid HIT™ program follows. The workouts themselves begin on page 209.

The table below compares the systems progression in the standard and rapid programs.

HIT™ Programs

	Standard HIT												
Program Week	1	2	3	4	5	6	7	8	9	10	11	12	13
Neuromuscular: High-cadence	X	X	X	X	X	X	X	X	X	X	X	X	X
Strength: Isolated leg	X	X	X	X	X	x							
Threshold				x	X	X	X	X	X	X	X	X	X
VO2 max					x	x	X	X	X	X	X	X	X
Anaerobic										X	X	X	X

	Rapid HIT									
Program Week	1	2	3	Transition Week	5	6	7	8	9	Event Week
Neuromuscular: High-cadence	x	x	x		x	x	x	x	x	
Strength: Isolated leg	X	X	X							
Threshold	X	X	X		X	X	X	X	X	
VO2 max					X	X	X	X	X	
Anaerobic	x	x	x		x	x	x	x	x	

Table 33. Standard and Rapid HIT™ programs compared.

The specific training program sequentially trains fitness systems for cyclists. During the 9 weeks, new exercises are added as others are dropped. It is generally a mistake for riders to perform the trainer workouts out of sequence.

This program is shorter than the Standard HIT™ program by a month. It assumes considerable aerobic development. Strength training is abbreviated, and high-end aerobic and anaerobic development is emphasized.

5-Week Rapid HIT™ Program

Have only a month to peak for your event?

If you do not have enough time in your schedule for the 9-week program, skip the first four weeks. You will miss the strength work of the first few sessions.

Strength work provides important benefits, but it takes several weeks to recover from such work. If you do not have the time to do so, you might end up slower.

Where to Workout

Workouts can be performed on stationary trainer, on a velodrome (track), on the road, or on dirt (cross-country). The stationary trainer is preferred. The environment is controlled; the rider can concentrate on the work to be done. Hints for logging your workout on stationary trainer are discussed on page 138.

Although environment-specific workouts (velodrome, road, or dirt) are important, such workouts have limitations.

Track workouts do not allow for easily changed gear ratios, or the varied muscular stimulation that occurs between climbing and level-riding positions.

Road workouts are limited by changing terrain, traffic, traffic signals, potholes, and other considerations.

Dirt (cross-country) workouts are limited by changing terrain, rocks, ruts, and other obstacles.

Weekly Schedule

The high-intensity workouts are generally best-performed mid-week—for example, on Tuesdays and Thursdays.

Many racers will be racing some weekends during this program. It is difficult to race Saturday after a hard workout Thursday. If racing the following Saturday and Sunday, perform trainer workouts on Monday and Wednesday, or Tuesday and Wednesday. Alternatively, skip the second-day workout.

Performing two "all-out" workouts a week is plenty for most cyclists. Few cyclists should perform more than three hard workouts a week. In general, perform no more than three days of HIT™ workouts and/or racing a week.

In general, perform a recovery ride of 30 minutes to 2 hours on Monday and Friday. Depending upon your overall training level, ride a moderately-paced endurance ride on Wednesdays.

Generally participate in moderately-hard group rides or races on the weekends. Plan for about 30 minutes of high-threshold work (near time-trial type efforts) on one day of the weekend. Generally, do not work as hard as time trial pace: work about 10 beats per minute under time trial heart rate.

Perform up to two dozen short intervals (sprints) a week. About one-third should be 30 seconds in duration, one-third 15 seconds in duration, and one-third 5 seconds in duration. These can be performed as part of the HIT™ workouts, or on group rides. Although I have prescribed these exercises in the week-by-week HIT™ workouts that follow, as well as indicated them on the *Summary* on page 218, do not perform them at every opportunity indicated. One to two dozen short intervals a week is plenty. Three or four dozen is not better!

Workout Protocols

In the rapid HIT™ program that begins on page 209, I will use heart rate to help quantify aerobic workouts, and cadence to help specify neuromuscular (leg-speed) and strength workouts. Shorter anaerobic efforts will be performed "all-out."

Gearing suggestions are just general indications of where you might be. As discussed under *Resistance Varies* on page 131, different trainers have different power curves. It is impossible to specify gearing precisely.

Power ranges are also given. These are scaled to weight. As there is a great range in absolute fitness between, for example, a beginning 60-year-old woman, and a professional 25-year-old male, they are necessarily approximations.

The higher ranges apply to riders with a VO_2 max of about 70 milliliters per kilogram per minute. An example: A fit, regional elite male athletes such as a mid-pack US Cat 2 male racer.

The lower ranges apply to riders with a VO_2 max of about 50 milliliters per kilogram per minute. Examples include: Mid-pack beginning male racers; fit, established young masters female racers; or established old masters male riders. Said differently, examples include: A mid-pack US Cat 5 male racer; a US Cat 3, 35-year-old female racer; a 65-year-old US Cat 3 male racer.

For example, the exercise *stand climbing tempo* ranges from two to four-and-one-half watts per kilogram. For a 55-kilogram (121-pound) rider this is 110 to 220 watts. For a 70-kilogram (154-pound) rider this is 140 to 280 watts. A 121-pound 35-year-old Cat 3 woman might therefore climb steady tempo at 110 watts. A 154-pound Cat 2 man might therefore climb steady tempo at 280 watts.

For more information, see *Power-Based Training* on page 39.

Torque training applies to isolated-leg training. Crank torque ranges are quantified, but vary greatly among riders. As with power ranges, these are scaled to weight. The higher ranges apply to fit, regional elite male athletes. The lower ranges generally apply to beginning male racers; fit, established young masters female racers; or elite older masters male riders.

PowerTap measures wheel torque, and SRM does not display its crank torque measurements.

- Torque in pound-inches is power in watts divided by cadence multiplied by 85. Alternatively:
- PowerTap users: To convert wheel torque to crank torque, use the formula:
  Crank torque = wheel torque x (chainring teeth / cog teeth), or use the table on 62.
- SRM users: Consider using a secondary program to view crank torque.

By noting PowerTap wheel torque or SRM power in a given gear, you can gain insight into your relative torque values from workout to workout.

For more information, see *Torque-Based Training* on page 53.

Follow the progression principles outlined on page 92. *Record Session* means try to perform a personal best for this part of the workout. Record attempts may be on different dates than suggested depending upon your exact race schedule.

For more information on training and fitness standards for men and women, and masters by 5-year age groups, see the Appendix A: *Training & Fitness Standards for Excellence* on page 224.

The following is a brief description of the workout protocols used in the rapid 9-week program that follows.

Spin-up: A progressive exercise, increasing cadence 5 rpm every minute. Generally, use your easiest gear so that your ability to perform these exercises is not limited by heart rate or leg strength. Resistance on your trainer should be low. Start every trainer session with this warm-up. Power less than 150 watts.

ILT: Isolated leg training. Riding with one leg. The other leg is dangled, or supported on a stand or bike.

As you adapt, work on general leg strength by riding in moderate to big gears at 60 rpm. Initially heart rates will be below 75% for most riders. At moderate workloads, you will be able to concentrate on pushing down or pulling up. You may be able to ride in the aerobar position.

At hard workloads, you will not be as smooth. You will need to pull on the handlebars while you push forward or down with your leg. You will be using inertia to help get your leg back up for the next stroke. It is normal to hear a “whoomp” with each pedal stroke. If you are able to stay smooth, it means you are not training your downstroke quad and buttock muscles to their potential.

At high-power outputs, you will be pushing down with greater than body weight. Stabilize yourself with your arms. This is typically helpful at greater than 1.5 watts/kilogram. At greater than 2.0 watts/kilogram using both your hands on the same side of the handlebar as the leg performing the ILT makes the ILT easier to execute.

After adaptation, elite riders are able to perform this exercise at greater than 90% of maximum HR, at watts-per-kilogram power outputs of more than one-half their maximum ramped aerobic watts-per-kilogram power. For example, elite riders who have a maximum ramped aerobic power of 6 watts per kilogram are able to perform this exercise at 3.5 watts per kilogram.

3.5 watts per kilogram equates roughly to 5 pound-inches per kilogram of crank torque.

A cadence of 80 rpm, in an easy gear, preferentially works hip flexors and is more difficult for most riders to perform than 60-rpm work. The easy gear makes it more difficult to use inertia to help get your leg back up for the next stoke. A clunk at the bottom of the stroke reveals hip flexor weakness or lack of neuromuscular coordination. The 3-minute duration (for each leg) may be too long for beginners. Beginners may need to rest 15 seconds at the top of each minute.

4-Minute Intervals. Read the information starting on page 113 and on page 115

In general, when you are able to finish 3- to 4-minute intervals in the 100 to 110 rpm range, shift to a harder gear next time. Pace within each interval and from interval to interval to perform near the maximum work possible for the total number of intervals prescribed.

Vary hand position from drops to hoods to tops.

Heart rate: Aim for 80^{+}% to 90^{+}% of maximum at the end of each interval.

Power: 2.5 to 5 watts per kilogram. Average power for the last four intervals above 30-minute time-trial power.

10-Minute Intervals: Generally perform three 10-minute intervals. Perform the first and third intervals seated. Stand for the middle interval.
Have cadence rise 1 rpm each minute through interval. End with HR above 90% MHR on last two intervals.
Seated: Hardest gear to maintain cadence 90 to 105.
Standing. Cadence 50 to 65.

Sprint Intervals: Generally perform a mix of the following:

30-Second Sprint Intervals. Pace within each interval and from interval to interval to perform near the maximum work possible for the total number of intervals prescribed.
Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.
Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.
Sprint to 120 to 140 rpm.
Power at 3 to 8 watts/kg average power for the sprint.
For more information, see page 124.

15-Second Sprint Intervals. Perform these intervals almost "all-out" from the beginning of the intervals.
Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.
Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.
Although effort is anaerobic, do not expect anaerobic-level heart rates. (For more information about this, see page 38.)
Sprint to 120 to 140 rpm.
Power at 4 to 10 watts/kg average power for the sprint.
For more information, see page 124.

5-Second Sprint Intervals. Perform these intervals "all-out" from the beginning of the intervals. As soon as your cadence drops, stop.
Perform most of these intervals with hands in the drops and start out of the saddle. Alternately, lead with the left and right leg. After getting up to near full speed, it is okay to sit down.
Occasionally perform these intervals with hands on the hoods and initiate from a seated position—because sometimes there is no time to get to sprint position if someone else attacks or otherwise initiates a sprint.
Although effort is anaerobic, do not expect anaerobic-level heart rates. (For more information about this, see page 38.)
Sprint to 120 to 140 rpm.
Power at 5 to 12 watts/kg average power for the sprint.
For more information, see page 124.

Time Trials: Steady state riding, usually 20 to 30 minutes. Heart rate 80% to 92^{+}% of max.

Rest. In the exercises described below, generally, rest 1 minute between each exercise on a new line or where heart rate at the end of the interval is less than 75% of maximum.
Rest 2 minutes between each exercise group—exercises with a small paragraph space or where heart rate at the end of the interval is less than 80% of maximum.
Rest 3 minutes between individual and group exercises (sets and reps) where heart rate at the end of the interval is more than 80% of maximum.

Systems Trained by Workouts

As stated on page 148, the stationary trainer workout protocols sequentially train a number of cycling fitness systems. Table 34 lists fitness systems targeted in the 9-week rapid HIT™ program and the exercises that train them.

Fitness System	Exercises
Neuromuscular	Spin-up Spin Maximum spin ILT, cadence 80 rpm
Muscular Strength Fast-twitch Slow-twitch Both	 5-second maximum power intervals ILT, cadence 60 rpm ILT, cadence 60 rpm 10-minute intervals
Threshold/metabolic	10-minute intervals 20-30 minute time trials
VO_2	4-minute intervals 10-minute progressive intervals
Anaerobic	30-second intervals 10 to 15 second intervals 5-second maximum power intervals

Table 34. Systems trained by workouts.

Rapid 9-Week HIT™ Program

Week 1

Workout 1A, About 1.5 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops*. Moderate gear. Say 53/21. Power 1.0 to 3.5 watts/kg. Crank torque 1.5 to 5.0 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/19. Power 1.5 to 3.5 watts/kg. Crank torque 2.0 to 5.0 pound-inches/kg. P/T/C.

9 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 3 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 3 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 3 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 1B, About 1.5 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops*. Moderate gear. Say 53/19. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder moderate gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them "all out."

Each workout can be split in two. For example, the 10-minute intervals and sprints can be performed in a first workout on the road; the ILTs in a second workout on stationary trainer.
Practice sprints twice a week. They do not necessarily need to be performed on either HIT day.

Generally, rest 1 minute between each exercise on a new line. Rest 2 minutes between each exercise group—exercises with a small paragraph space. Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

*ILTs: Perform in various positions: each minute, alternate hands on tops and in drops.
Read more about how to perform sprint intervals on page 124.

Rapid 9-Week HIT™ Program

Week 2

Workout 2A, About 1.5 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops*. Harder gear. Say 53/19. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

9 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 3 sprints. Power average 3 to 10 watts/kg. Crank torque 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 3 sprints. Power average 4 to 12 watts/kg. Crank torque 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 3 sprints. Power average 5 to 15 watts/kg. Crank torque 5 to 13 pound-inches/kg. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105^+ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 2B, About 1.5 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops*. Harder gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Slightly harder gear. Say 53/15. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

Plan for an ILT record next session.

Sprints on another training day or as in 2A. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^+ rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them “all out.”

Each workout can be split in two. For example, the 10-minute intervals and sprints can be performed in a first workout on the road; the ILTs in a second workout on stationary trainer.
Practice sprints twice a week. They do not necessarily need to be performed on either HIT day.

Generally, rest 1 minute between each exercise on a new line. Rest 2 minutes between each exercise group—exercises with a small paragraph space. Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^+% of max.

*ILTs: Perform in various positions: each minute, alternate hands on tops and in drops.
Read more about how to perform sprint intervals on page 124.

Week 3

Workout 3A, About 1.5 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

ILT Record Session

ILT 50-60 rpm. 3 minutes. Tops, drops, tops*. Harder gear. Say 53/17. Power 1.5 to 3.5 watts/kg. Crank torque 2 to 5 pound-inches/kg. P/T/C.

ILT 80 rpm. 3 minutes. Tops, drops, tops. Easy gear. Say 39/27. Power <1 watt per kilogram. T/C.

ILT 50-60 rpm. 3 minutes. Tops, drops, tops. Still harder gear. Say 53/14. Power 2 to 4 watts/kg. Crank torque 3 to 6 pound-inches/kg. P/T/C.

9 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint for 30 seconds at the top of each minute for 3 sprints. 3 to 10 watts/kg. P/T.

Shift one cog smaller (harder). Sprint for 15 seconds at the top of each minute for 3 sprints. 4 to 12 watts/kg average power for the sprint. P/T.

Shift another/one cog smaller. Sprint for 5 seconds at the top of each minute for 3 sprints. 5 to 15 watts/kg average power for the sprint. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105$^+$ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 3B, About 1.25 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105$^+$ rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.

Rapid HIT workout 3A can be split in two. For example, the 10-minute intervals and sprints can be performed in a first workout on the road; the ILTs in a second workout on stationary trainer.

Practice sprints twice a week. They do not necessarily need to be performed on either HIT day.

Generally, rest 1 minute between each exercise on a new line. Rest 2 minutes between each exercise group—exercises with a small paragraph space. Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80$^+$% of max.

*ILTs: Perform in various positions: each minute, alternate hands on tops and in drops.
Read more about how to perform sprint intervals on page 124.

Rapid 9-Week HIT™ Program

Week 4

Take a rest from high-intensity training. Ride moderately on the road, looking for hilly rides.

Rapid 9-Week HIT™ Program

Week 5

Workout 5A, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

Plan for a 10-minute interval record next session.

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. Increase cadence each minute. Aim for HR about 80^{+}% of max at end of first, higher for next three, $90\%^{+}$ for the last two. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. HR/P.

12 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 4 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 4 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 4 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 5B, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. Increase cadence each minute. Aim for HR about 80^{+}% of max at end of first, higher for next three, $90\%^{+}$ for the last two. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. HR/P.

20-minute time trial. Moderate gear. Starting cadence 75 to 85 rpm. Increase cadence 1 rpm/minute through interval. 2.5 to 4.5 watts/kg. HR about 80% of max after 10 minutes. End with HR >90% MHR. HR/P.

Sprints on another training day or as in 2A. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them “all out.”

Rapid HIT workout 5A can be split in two. The 10-minute intervals can be performed in the first workout, the ILTs and sprints in a second workout.
Practice sprints twice a week. They do not necessarily need to be performed today.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Rapid 9-Week HIT™ Program

Week 6

Workout 6A, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-Minute Interval Record Session

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

As a record session, choose a starting cadence 1-3 rpm higher than previously. When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. Increase cadence each minute. Aim for HR about 80^{+}% of max at end of first, higher for next three, 90%$^{+}$ for the last two. HR/P.

12 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 4 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 4 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 4 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 6B, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. Increase cadence each minute. Aim for HR about 80^{+}% of max at end of first, higher for next three, 90%$^{+}$ for the last two. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. HR/P.

Plan for a 4-minute interval record next session.

20-minute time trial. Moderate gear. Starting cadence 75 to 85 rpm. Increase cadence 1 rpm/minute through interval. 2.5 to 4.5 watts/kg. HR about 80% of max after 10 minutes. End with HR >90% MHR. HR/P.

Plan for a 45- to 60-minute TT record this coming weekend. HR/P.

Sprints on another training day or as in 2A. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them “all out.”

Rapid HIT workout 6A can be split in two. The 10-minute intervals can be performed in the first workout, the ILTs and sprints in a second workout.
Practice sprints twice a week. They do not necessarily need to be performed today.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Rapid 9-Week HIT™ Program

Week 7

Workout 7A, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

4-Minute Interval Record Session

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. As a record session, choose a starting cadence for the intervals 1-3 rpm higher than previously. Aim for HR about 80^{+}% of max at end of first, higher for next two, $90\%^{+}$ for the last three. Power 2 to 5 watts/kg. Average power for the last four intervals above 30-minute time-trial power. HR/P.

9 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 3 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 3 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 3 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 7B, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. Increase cadence each minute. Aim for HR about 80^{+}% of max at end of first, higher for next three, $90\%^{+}$ for the last two. Power 2 to 5 watts/kg. Average power for the last three intervals above 30-minute time-trial power. HR/P.

25-minute time trial. Moderate gear. Starting cadence 70 to 80 rpm. Increase cadence 1 rpm/minute for the first 10 minutes, then 1 rpm/two minutes for the last 15 minutes. 2.5 to 4.5 watts/kg. HR about 80% of max after 10 minutes. End with HR >90% MHR. HR/P.

Plan for a time trial record next session.

Sprints on another training day or as in 7A. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them "all out."

Rapid HIT workout 7A can be split in two. The 10-minute intervals can be performed in the first workout, the ILTs and sprints in a second workout.
Practice sprints twice a week. They do not necessarily need to be performed today.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Rapid 9-Week HIT™ Program

Week 8

Workout 8A, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. Increase cadence each minute. Aim for HR about 80^{+}% of max at end of first, higher for next three, $90\%^{+}$ for the last two. HR/P.

12 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 4 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 4 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 4 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105^{+} rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 8B, About 1.25 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

No 4-minute intervals today.

Plan for a 4-minute interval record next session.

30-Minute Time Trial Record Session

30-minute time trial. Moderate gear. Starting cadence 70 to 80 rpm. Increase cadence 1 rpm/minute for the first 10 minutes, then 1 rpm/two minutes for the last 20 minutes. 2.5 to 4.5 watts/kg. HR about 80% of max after 10 minutes. End with HR >90% MHR. HR/P.

Sprints on another training day or as in 7A. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^{+} rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them “all out.”

Rapid HIT workout 8A can be split in two. The 10-minute intervals can be performed in the first workout, the ILTs and sprints in a second workout.

Practice sprints twice a week. They do not necessarily need to be performed today.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^{+}% of max.

Rapid 9-Week HIT™ Program

Week 9

Workout 9A, About 2 Hours

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg. C.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg.

10-minute intervals. Perform three. Moderate gear. Perform the first and third intervals seated. Stand for the middle interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on last two intervals. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

4-Minute Interval Record Session

Six 4-minute intervals. Cadence 85 to 110 rpm. 39/14. 2.5 to 5 watts/kg. As a record session, choose a starting cadence for the intervals 1-3 rpm higher than previously. Aim for HR about 80^+% of max at end of first, higher for next two, $90\%^+$ for the last three. HR/P.

9 sprints.

Start in same gear as the seated 10-minute-intervals above. Sprint to 120 to 140 rpm for 30 seconds at the top of each minute for 3 sprints. Power average 3 to 10 watts/kg. Crank torque average 1.5 to 5 pound-inches/kg. P.

Shift one cog smaller (harder). Sprint to 120 to 140 rpm for 15 seconds at the top of each minute for 3 sprints. Power average 4 to 12 watts/kg. Crank torque average 3 to 8 pound-inches/kg. P/T.

Shift another/one cog smaller. Sprint to 120 to 140 rpm for 5 seconds at the top of each minute for 3 sprints. Power average 5 to 15 watts/kg. Crank torque average 5 to 13 pound-inches/kg. P/T.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 5 minutes 105^+ rpm. Power <2 watts/kg. C.

Intensity Measures

C = Cadence (rpm) determines the intensity
HR = Heart-rate percentage (aerobics) determines the intensity
P = Power determines the intensity
T = Torque determines the intensity
HR/P = Both heart rate and power determine the intensity.

Workout 9B, About 1 Hour

Spin 60 to 120 rpm. Increase 5 rpm/minute. Easiest gear. Power <1.5 watts/kg.

Spin 80 to 150 rpm. Increase 5 rpm/15 seconds. Easiest gear. Power <2 watts/kg. C.

10-minute intervals. Perform two of these. Moderate gear. Perform the first interval seated. Stand for the second interval. Increase cadence 1 rpm/min through interval. 2.5 to 5 watts/kg. End with HR >90% MHR on each interval. HR/P.

When seated, select your gear so that your starting cadence will be between 90 and 95 rpm, finishing cadence between 100 and 105 rpm.

When standing, select your gear so that your starting cadence will be between 50 and 55 rpm, finishing cadence between 60 and 65 rpm.

Spin-up 60 to 125 rpm. Increase 5 rpm/15 seconds; then back down and hold 10 minutes 105^+ rpm. Power <2 watts/kg. C.

Notes

Read the general workout information on pages 113, 148, and 204.
Power, gearing, and rpm values are only suggestions.
Learn and adapt to exercises before performing them “all out.”

Rapid HIT workout 9A can be split in two. The 10-minute intervals can be performed in the first workout, the ILTs and sprints in a second workout.
Practice sprints twice a week. They do not necessarily need to be performed today.

Generally, rest 1 minute between each exercise on a new line.
Rest 2 minutes between each exercise group—exercises with a small paragraph space.
Rest 3 minutes between individual and group exercises (sets and reps) where your heart rate gets to 80^+% of max.

Summary: Rapid 5 to 9 Week HIT™ Programs

Week	Date Example	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total
	Focus →	Easy	Strength, CV	Endurance	Strength &	Recovery	Group	Group/Race	Estimate
	Monday is		VO_2	Anaerobic	Threshold		Hills	Intervals	
1	**June 2**	10–15	3x10’	50	ILT	10–50	40	60, including	275
	Phase 1		ILT	± Sprints	3x10’		± 3-9 Sprints	30’ TT-10 bpm	
			± 9 Sprints					± 3-9 Sprints	
2	**June 9**	10–15	3x10’	50	ILT	10–50	40	60, including	275
	Phase 1		ILT	± Sprints	3x10’		± 3-9 Sprints	30’ TT-10 bpm	
			± 9 Sprints		± 9 Sprints			± 3-9 Sprints	
3	**June 16**	10–15	3x10’	50	3x10’	10–50	40	60, including	275
	Phase 1		**ILT Record***	± Sprints			± 3-9 Sprints	30’ TT-10 bpm	
			± 9 Sprints					± 3-9 Sprints	
4	**June 23**	10–15	Hills, mod	50	Hills, mod	10–50	40	60, including	275
	Transition		± 9 Sprints	± Sprints	± 9 Sprints		± 3-9 Sprints	30’ TT-10 bpm	
								± 3-9 Sprints	
5	**June 30**	10–15	3x10’	50	6x4’	10–50	40	60, including	275
	Phase 2		6x4’	± Sprints	20’ TT		± 3-9 Sprints	30’ TT -10 bpm	
			± 12 Sprints		± 9 Sprints			± 3-9 Sprints	
6	**July 7**	10–15	**3x10’ Record***	50	6x4’	10–30	40	60, including	250
	Phase 2		6x4’	± Sprints	20’ TT		± 3-9 Sprints	**45-60’ TT Record***	
			± 12 Sprints		± 9 Sprints				
7	**July 14**	10–15	3x10’	50	6x4’	10–20	40	60, including	225-250
	Phase 2		**6x4’ Record***		25 min TT		± 3-9 Sprints	30’ TT-10 bpm	
			± 9 Sprints		± 9 Sprints			± 3-9 Sprints	
8	**July 21**	10–15	3x10’	50	**30’ TT Record***	10–20	40	60, including	225-250
	Phase 2		6x4’		± 9 Sprints		± 3-9 Sprints	30’ TT-10 bpm	
			± 12 Sprints					± 3-9 Sprints	
9	**July 28**	10–15	3x10’	50	2x10’	10–20	40	Ride course	225
	Phase 2		**6x4’ Record***		± 9 sprints				
			± 9 Sprints						
	August 4	Ride course	Time Trial	Easy	RR	RR	Crit	Crit	200

Table 35. Summary overview of rapid 9-Week HIT™ peaking program for top-level masters rider in preparation for Masters Nationals. The weekly training volumes below are based on a moderate-intensity riding level of 300 miles per week, typical of Cat 1 women, Cat 2 men, and top-level male masters riders to age 50. For other groups, and for more information, read the Part 5 introduction on page 204. Sprints are generally performed two or three days a week. *Record means try to perform a personal best for this part of the workout.

Rapid 9-Week HIT™ Program

Workout Recording Example

Here is an example of a heart-rate, cadence, and power recording from Rapid HIT™ workout.

Rapid Workout 2B Recording

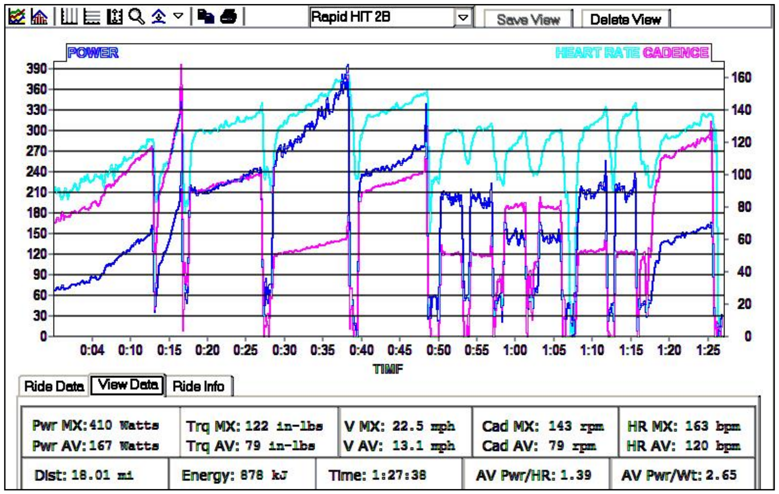


Figure 163. Rapid HIT workout 2B. PowerTap download. Heart rate, turquoise; cadence, pink; power, blue; and torque, black. This athlete weighs 63 kilograms (138 pounds); maximum heart rate is 190.

***Spin-Ups:* Two: The first from 60 rpm to 120 rpm and the second from 80 rpm to 140 rpm.**

***10-Minute Intervals:* The first, seated, in aerobars, is performed in a 38/17 from 90 to 100 rpm averaging 220 watts. The second, standing, is performed in a 55/13 from 50 to 60 rpm averaging 310 watts. The final, seated, in aerobars, is performed in a 38/16 from 90 to 100 rpm averaging 250 watts. Heart rate averages 130, 145, and 140 bpm respectively.**

***ILTs:* Three sets, performed in 55/14, 55/27, and 55/14 at 50, 80, and 52 rpm respectively. Power averages 210 and 220 watts in the first and third set.**

Part 6: Interval Quiz

1. For the majority of riders, the most generally productive interval duration is
- **A.** 15 seconds
- **B.** 30 seconds
- **C.** 1 minute
- **D.** 3 to 5 minutes
- **E.** 8 to 10 minutes

2. Intervals should be part of training
- **A.** Thursdays in the preparation period
- **B.** All year round
- **C.** At certain periods during the year

3. When performing hard regular work, such as 4-minute intervals, establish a breathing rhythm
- **A.** 2 minutes into the interval
- **B.** 1 minute into the interval
- **C.** 30 seconds before starting
- **D.** Before you start

4. If the workload is the same, a higher (bigger) gear and lower rpm means
- **A.** More aerobic work is done
- **B.** More muscular work is done
- **C.** More neuromuscular work is done

5. Muscle soreness is more likely to result from
- **A.** Slow rpm, high power output
- **B.** Fast rpm, low power output

6. When performing six 3-minute intervals
- **A.** Do each interval as hard as possible to complete each interval
- **B.** Do the first interval as hard as possible. Try to put more in each successive interval
- **C.** Pace yourself, going slightly harder each time

7. Optimal recovery time between six 3-minute intervals is
- **A.** 15 to 30 seconds
- **B.** 1 minute
- **C.** 3 minutes
- **D.** 5 minutes

8. To train maximum oxygen uptake (VO_2) perform intervals for
- **A.** 15 to 30 seconds
- **B.** 3 to 5 minutes
- **C.** 8 to 10 minutes
- **D.** Any of the above
- **E.** None of the above

9. Gear selection for intervals
- **A.** You must be in the big ring
- **B.** You must be in the small ring
- **C.** Choose the gearing that results in the cadence range you are targeting

10. To train for improved sprinting, perform intervals only at high cadence
- **A.** True
- **B.** False

11. Relative to 3-minute intervals, 30-second intervals are generally performed at speed levels

A. About the same as 3-minute intervals
B. About 30% greater
C. About 50% greater
D. About 100% greater

12. Intervals can only be done

A. On hills
B. On the flats
C. On a stationary trainer
D. On the track
E. All of the above

13. Ancillary equipment for stationary trainer work includes all of the following except

A. Heart-rate monitor to help quantify aerobic work
B. Wood blocks or other method to raise front of trainer
C. Fans for cooling
D. TV or headphones for distraction
E. Carbs in solution

14. Intervals should be performed

A. Once a week
B. Twice a week
C. More than twice a week
D. Two or three days in a row
E. Could be any of the above

15. Heart-rate target, on average, at the end of 3- or 4-minute intervals, is at least

A. 70% to 75% of maximum heart rate
B. 80% to 85% of maximum heart rate
C. About 90% of maximum heart rate
D. Whatever you do, don't go anaerobic!

16. The highest blood lactate levels are recorded after efforts lasting

A. 15 seconds
B. 30 seconds
C. 1 minute
D. 3 to 4 minutes.

17. Track pursuit distance for professional riders is 5K, for Elite riders it is 4K, for Masters it is 3K, and for junior women, it is 2K. This approach of reduced distance

A. Is a good idea for younger or weaker riders who do not have the stamina of elite or professional men
B. Makes no physiologic sense

18. When planning or performing an interval session

A. Know before you start how many intervals you are going to attempt
B. See how it goes; when you feel tired, stop.
C. Stop when pizza arrives

Interval Quiz—Answers

1. D. Although a wide variety of intervals is wise, intervals lasting 3 to 5 minutes help most riders the most. Perhaps the next most productive interval length is 15 to 30 seconds.

2. C. Intervals *can* be performed all year-round. A minority of coaches advises year-round interval training, and adding endurance during the racing season. However, most riders do better performing and emphasizing this type of physically and psychologically demanding training only at certain times of the year.

3. D. Regular breathing is the most common means athletes use to help maintain a narrow, interval focus, which helps hard work. Many riders ill-advisedly hold their breath at the beginning of hard work. Get into your breathing rhythm about 10 seconds before you start working.

4. B. Big gears, slow cadence emphasizes muscular fitness. Small gears, fast cadence emphasizes neuromuscular work. Maximum aerobic capacity is trained at a cadence about 100.

5. B. Faster rpm often means that muscles are lengthening before relaxation, while still contracted (eccentric exercise). This is associated with delayed onset muscle soreness (DOMS).

6. C. Although coaches and athletes sometimes maintain otherwise, if you truly perform the first interval as hard as possible, you cannot go again at the same intensity. Whether it is a conscious or unconscious strategy, you must pace. That is why, as in question 18, it is usually preferable to know ahead of time what the session program is.

7. C. Optimal recovery time depends on the length of the work interval, and the purpose of the interval. In general, the most work for six 3-minute intervals will be accomplished with 3-minute recoveries. Shorter periods will not allow enough recovery; longer periods will result in too much cooling-down.

8. D. 3 to 5 minutes intervals are sometimes called VO_2 intervals. Intervals of this duration are generally the foolproof way to train maximum oxygen uptake because the hard workloads and the recovery periods between them are relatively easy to get right. Maximum oxygen uptake can also be trained with shorter intervals if the recovery between intervals is also short. If 8- to 10-minute intervals are performed with an increasing workload, maximum oxygen uptake can also be trained.

9. C. If performed on a stationary trainer, gear selection depends upon the type of interval being performed, the fitness of the athlete, and the resistance that the trainer provides. One cannot, ahead of time, prescribe gearing for all.

10. B. Intervals at high cadence *do* help sprinting. They help the leg speed that is required to successfully sprint. However, short intervals in a huge gear and low rpm also help the torque that is required initiating a jump.

11. B. About 30% faster, or 100% more power. (Power rises between the square and the cube of speed.)

12. E. One *can* perform intervals almost anywhere. The stationary trainer is preferable because of its ability to tune precisely the effort, free of other distractions.

13. D. TV or headphone distraction may help some riders during steady-state efforts. For high-intensity efforts, narrow internal focus, not distraction, works best.

14. E. Could be any of the above. At some times of the year, intervals are not performed at all. Elite riders may string several days of intervals together in a row. During HIT phases, beginners and intermediates do best to perform intervals once or twice a week.

15. C. Intervals are hard work, and there certainly is an anaerobic component. The first interval or two may be in the mid 80% range. The last couple may be 95^{+}% for some riders. Most adapted riders average about 90%

16. C. One-minute intervals result in the highest lactate levels. Shorter intervals are not long enough for levels to rise as high; longer intervals do not result in enough intensity. It is for this reason that 1-minute intervals are sometimes called max lactate intervals. Such efforts are also called lactic acid tolerance training.

17. B. Over-shortening the pursuit distance, resulting in a shorter competition time for "weaker" riders is misguided. Shorter intervals are not easier. They result in the demand for different physiologic systems.

18. C. Definitely. Not. Correction. Choose A.

Appendix A: Training & Fitness Standards for Excellence

What follows are training and fitness testing standards for top-category riders. Excellent riders podium frequently. Very good riders, whose values average 5% less, podium sometimes. Good riders' values average 15% less; they finish mid-field. Fair riders' values average 25% less; they finish in the second half of field.

These standards have been developed from my own experience, the experience of other coaches, studies of riders, and rider surveys.

Divisions

Training and fitness standards are given for four groups: Men, women, masters men, and masters women.

For men and women, road and track racing categories (Cat 5 through Pro) are noted above mountain bike categories (Beginner through Pro).

Competition Arena

Standards that apply to Category 5, 4, 3, and 2 men and women road racers and track racers, and beginner, expert and elite mountain bikers, and masters racers under age 50 apply to local or regional races.

Standards in some areas of the country are higher than in others. For example, California standards are higher than those in other areas are.

Category 1 road and track racers, elite mountain bikers, and masters racers aged 50 and over apply to regional or national competition. (In many areas of the country older masters racers will often podium just by entering.)

Lower Categories Self-Limiting

Excellent lower category racers do not remain lower-category for long.

Training Standards

Best Case Scenario

Standards are based on ideal conditions. Keep in mind that ability to train depends upon environment (climate, local topography); absence of sickness or injury; and interpersonal, job, or other demands. Many racers are able to perform well with less than perfect training.

Training Years

Experienced competitors may be able to compete at a given level with less than standard training volume.

Outliers

Some exceptional athletes have enormous or tiny volumes of training intensity.

For example, one of the best masters climbers in the US, age category 55$^+$, climbs roughly 2,000,000 feet per year—double the level of many European professional cyclists.

Races Per Year

These include training races for lower categories. Many excellent riders, especially mountain bikers, race fewer times than the standard.

Hours

I consider riding like any other job. Employers generally pay for restroom and short breaks, but not for lunch hours. I consider training hours to include short breaks, but not major meal stops. For example, I include stoplights and repairing flat tires in training time. It is also easier this way for most riders to keep track of their hours.

If your computer records only actual riding time and you are not including even stoplights in your training time, subtract 20% from the standards.

Workouts Per Week

Riders may have two, and occasionally three workouts in one day. For example, a track rider might have a weight room workout in the morning, and easy ride in the middle of the day, and an interval workout on stationary trainer in the early evening.

Training Weeks Per Year

Training weeks per year range from 38 to 45. Two to four weeks per year may be completely off the bike. “Vacation” and “sick” days account for the rest.

Many excellent riders live in climates that do not allow year-round on or off-road training. Most racers use stationary trainers. Many also cross-train.

Fitness Standards

For more detailed information about the elements of cycling fitness and fitness testing protocols, see the ABC handouts *Fitness Elements*, *Fitness Testing*, and *Max Aerobic Power Testing* available through http://arniebakercycling.com.

Composite Excellence

Keep in mind that no rider is the perfect combination of best climber, flat-land time trialists, and sprinter in his or her category.

Standards apply to relevant events (e.g. climbing rates to climbing races, anaerobic power to sprint events).

Some standards are almost mutually exclusive. In order to be a great sprinter, riders must have fast-twitch muscle strength. Fast-twitch fibers are larger and heavier. This makes it rare for excellent sprinters to achieve the excellent climbing weight-per-inch standards.

Riders exceptional in one area may compensate in another area, or not.

Outliers

Some riders with less than excellent fitness are able to gain excellent results due to exceptional strategy and tactics, bike handling, nutrition, equipment, or psychology.

Best Performance

Remember, fitness-testing standards are best performances: single performances that occur when healthy, rested, warmed-up, and motivated.

Standard training intensities may be considerably lower. For example, a session of 4-minute VO_2-type intervals may be performed at 25% less than the maximum power output of a single best performance.

Maximum Heart Rate

Formulas for maximum heart rate based on age are misleading. Individuals must determine their own maximum heart rates.

Maximum heart rate is not related to performance; the tables do not include it.

However, it is necessary to know maximum heart rate for submaximum testing.

For more information about maximum heart rate, see page 34.

Selected, Representative Standards

Representative standards are sometimes given.

For example, absolute VO_2 max standards for 70-kilogram (154 pound) men and 55-kilogram (121 pound) women are given. Climbing rates for 6% and 8% grades are given.

Muscular ILT

Excellent riders generally perform a maximum 3-minute ILT set at 5/8th max ramped power.

Men

Road/Track/ Mountain Bike	Cat 5 Beginner	Cat 4 Beginner	Cat 3 Expert	Cat 2 Elite	Cat 1 S-Pro	US Pro	Euro Pro
Training							
Training years	1	2	5	7	10	>10	>10
Races per year. Mt bikers may half.	10	15	20	40	60	80	100
Annual hours	550	650	750	850	1,050	1,250	1,350
Workouts / week	5	6	6	7	7	8	8
Annual miles	7,000	8,000	10,500	12,500	15,000	18,000	20,000
Annual climbing, feet	400K	480K	630K	750K	925K	1,000K	1,100K
Training weeks / year	40	40	42	42	44	45	45
Weekly volume, hours	14	16	18	20	24	28	30
Weekly volume, miles	175	200	250	300	350	400	450
Weekly climbing, feet. Big weeks will double	10,000	12,000	15,000	18,000	21,000	23,000	25,000
Fitness							
Anthropomorphic							
Percent body fat		<12%	<10%	<7%			<5%
Weight, pounds: (Inches > 60” X 5) +:	110	105	105	105	100	100	100
Neuromuscular—Leg Speed							
RPM, progressive, 60 second increments	125	130	135	140	145	150	150
RPM, progressive, 30 second increments	135	140	150	155	160	165	170
RPM, progressive, 15 second increments	145	155	165	170	175	180	185
Muscular							
ILTs 60 rpm, 3 min, watts/kg	2.6	2.8	3.4	3.7	4.0	4.2	4.5
ILTs 80 rpm, min	3	4	5	6	7	8	9
Aerobic							
Max							
VO_2 max, absolute, L/min, 70 kg (154 lb)	4.2	4.5	4.9	5.2	5.6	6.0	6.3
VO_2 max, mass scaled, ml/kg/min	60	65	70	75	80	85	90

Men (continued)

Road/Track/ Mountain Bike	Cat 5 Beginner	Cat 4 Beginner	Cat 3 Expert	Cat 2 Elite	Cat 1 S-Pro	US Pro	Euro Pro
Ramped max power, watts/kg	4.5	5.0	5.5	6.0	6.5	6.8	7.2
Economy, watts/L/min	72	73	74	75	76	77	78
Max climbing rate (5 min), 6% grade, feet per hr	4,000	5,000	5,400	5,800	6,200	6,600	7,000
Max climbing rate (5 min), 8% grade, feet per hr	4,500	5,400	5,850	6,300	6,750	7,200	7,500
Flat or climbing TT power, watts/kg (% max)	2.8 (62)	3.2 (64)	3.9 (71)	4.6 (76)	5.1 (78)	5.6 (80)	6.0 (80)
Flat or climbing TT power, watts, 70 kg	200	225	275	325	360	390	420
Aerodynamic-Aerobic							
Flat TT VO_2, absolute, L/min, 70 kg (154 lb)	3.5	3.8	4.2	4.5	4.9	5.2	5.6
Flat TT VO_2, mass scaled, ml/kg/min	50	55	60	65	70	75	80
Flat TT time 20K, standard aero*	33	31	29	27	26	25.5	25
Flat TT 20K 80% max HR, or non-aero	35	33	31	28.5	27	36.5	26
Climbing-Aerobic							
30 min 6% climb, 80% max HR, feet per hr	3,000	3,400	3,700	4,000	4,250	4,500	5,000
30 min 8% climb, 80% max HR, feet per hr	3,300	3,800	4,100	4,400	4,700	5,000	5,500
30 min 6% climb, max, feet per hr	3,300	3,800	4,100	4,400	4,700	5,000	5,500
30 min 8% climb, max, feet per hr	3,600	4,200	4,500	4,800	5,100	5,400	6,000
Anaerobic							
Anaerobic power 10 sec, watts/kg	12	14	16	18	20	22.5	25
Anaerobic power 10 sec, watts/70 kg (154 lb)	850	1,000	1,120	1,250	1,400	1,575	1,750
Torque, peak, crank, pound-inches	750	900	1000	1,100	1,250	1,400	1,600
Anaerobic power 10 sec, X TT power	2.9	3.2	3.4	3.5	3.6	3.7	3.9
Anaerobic power 30 sec, peak							
Anaerobic power 30 sec, average							
200m time, fast track, seconds	14.0	12.5	11.5	11.0	10.5	10.3	10.2
1000m time, fast track	1:19	1:17	1:15	1:13	1:10	1:07	1:03

Table 36. Training and fitness standards for excellence. Men.
***Standard aero: Skinsuit, aero helmet, disc wheel, standard frame, clip-ons.**
Where absolute values are given, may assume 70-kilogram (154 pound) rider.

Women

Road/Track/ Mountain Bike	Cat 4 Beginner	Cat 3 Beginner	Cat 2 Expert	Cat 1 Elite	World Class
Training					
Training years	2	5	7	10	>10
Races per year. Mt bikers may half.	10	15	20	40	60
Annual hours	550	700	850	1000	1250
Workouts / week	5	6	7	7	8
Annual miles	7,000	9,000	11,000	13,500	16,000
Annual climbing, feet	300K	400K	600K	800K	1,000K
Training weeks / year	38	42	44	45	45
Weekly volume, hours	14	17	20	24	28
Weekly volume, miles	180	200	250	300	350
Weekly climbing, feet. Big weeks will double	8,000	9,500	13,500	18,000	22,000
Fitness					
Anthropomorphic					
Percent body fat	<20%	<17%	<14%	<12%	<10%
Weight, pounds: (Inches > 60” X 4) +:	105	105	100	100	100
Neuromuscular—Leg Speed					
RPM, progressive, 60 second increments	120	130	140	145	150
RPM, progressive, 30 second increments	130	140	155	160	165
RPM, progressive, 15 second increments	145	155	170	175	180
Muscular					
ILTs 60 rpm, 3 min, watts/kg	2.5	2.8	3.1	3.4	3.7
ILTs 80 rpm, min	3	3	4	5	6
Aerobic					
Max					
VO_2 max, absolute, L/min, 55 kg (121 lb)	3.0	3.3	3.6	3.9	4.1
VO_2 max, mass scaled, ml/kg/min	55	60	65	70	75

Women (continued)

Road/Track/ Mountain Bike	Cat 4 Beginner	Cat 3 Beginner	Cat 2 Expert	Cat 1 Elite	World Class
Ramped max power, watts/kg	4.0	4.5	5.0	5.5	6.0
Economy, watts/L/min	71	72	73	74	75
Max climbing rate (5 min), 6% grade, feet per hr	3,600	4,000	5,000	5,400	5,800
Max climbing rate (5 min), 8% grade, feet per hr	4,000	4,500	5,400	5,850	6,300
Flat or climbing TT power, watts/kg (% max)	2.4 (60)	2.8 (62)	3.2 (64)	3.9 (71)	4.6 (76)
Flat or climbing TT power, watts, 55 kg	135	155	175	215	255
Aerodynamic-Aerobic					
Flat TT VO_2, absolute, L/min, 55 kg (121 lb)	2.5	2.8	3.0	3.3	3.5
Flat TT VO_2, mass scaled, ml/kg/min	45	50	55	60	65
Flat TT time 20K, standard aero*	35	33	31	29	27
Flat TT 20K 80% max HR, or non-aero	38	35	33	31	28.5
Climbing-Aerobic					
30 min 6% climb, 80% max HR, feet per hr	2,700	3,000	3,400	3,700	4,000
30 min 8% climb, 80% max HR, feet per hr	3,000	3,300	3,800	4,100	4,400
30 min 6% climb, max, feet per hr	3,000	3,300	3,800	4,100	4,400
30 min 8% climb, max, feet per hr	3,300	3,600	4,200	4,500	4,800
Anaerobic					
Anaerobic power 10 sec, watts/kg	10	12	14	16	18
Anaerobic power 10 sec, watts/55 kg (121 lb)	550	660	770	880	1,000
Torque, peak, crank, pound-inches	500	600	700	800	900
Anaerobic power 10 sec, X TT power	2.7	2.9	3.2	3.4	3.5
Anaerobic power 30 sec, peak					
Anaerobic power 30 sec, average					
200m time, fast track, seconds	15.0	14.0	12.5	11.5	11.0
1000m time, fast track	1:20	1:19	1:17	1:15	1:13

Table 37. Training and fitness standards for excellence. Women.
***Standard aero: Skinsuit, aero helmet, disc wheel, standard frame, clip-ons.**
Where absolute values are given, may assume 55-kilogram (121 pound) rider.

Masters Men

Age	80	70	60	50	40	30
Training						
Training years	>5	>10	>10	>10	>10	>10
Races per year. Mt bikers may half.	10	15	20	30	40	60
Annual hours	450	550	675	750	880	1,050
Workouts / week	5	5	6	6	7	7
Annual miles	6,000	7,000	8,500	10,500	13,200	15,000
Annual climbing, feet	230K	320K	500K	630K	800K	950K
Training weeks / year	38	40	42	42	44	44
Weekly volume, hours	12	14	16	18	20	24
Weekly volume, miles	160	175	200	250	300	350
Weekly climbing, feet. Big weeks will double	6,000	8,000	12,000	15,000	18,000	22,000
Fitness						
Anthropomorphic						
Percent body fat	<15%	<13%	<11%	<8%	<7%	
Weight, pounds: (Inches > 60" X 5) +:	110	110	105	105	100	100
Neuromuscular—Leg Speed						
RPM, progressive, 60 second increments	120	125	130	135	140	145
RPM, progressive, 30 second increments	130	135	140	150	155	160
RPM, progressive, 15 second increments	140	145	155	165	170	175
Muscular						
ILTs 60 rpm, 3 min, watts/kg	2.5	2.8	3.1	3.4	3.7	4.0
ILTs 80 rpm, min	3	3	4	5	6	7
Aerobic						
Max						
VO_2 max, absolute, L/min, 70 kg (154 lb)	3.8	4.2	4.5	4.9	5.2	5.6
VO_2 max, mass scaled, ml/kg/min	55	60	65	70	75	80
Ramped max power, watts/kg	4.0	4.5	5.0	5.5	6.0	6.5

Masters Men (continued)

Age	80	70	60	50	40	30
Economy, watts/L/min	71	72	73	74	75	76
Max climbing rate (5 min), 6% grade, feet per hr	3,600	4,000	5,000	5,400	5,800	6,200
Max climbing rate (5 min), 8% grade, feet per hr	4,000	4,500	5,400	5,850	6,300	6,750
Flat or climbing TT power, watts/kg (% max)	2.4 (60)	2.8 (62)	3.2 (64)	3.9 (71)	4.6 (76)	5.1 (78)
Flat or climbing TT power, watts, 70 kg	175	200	225	275	325	360
Aerodynamic-Aerobic						
Flat TT VO_2, absolute, L/min, 70 kg (154 lb)	3.1	3.5	3.8	4.2	4.5	4.9
Flat TT VO_2, mass scaled, ml/kg/min	45	50	55	60	65	70
Flat TT time 20K, standard aero*	35	33	31	29	27	26
Flat TT 20K 80% max HR, or non-aero	38	35	33	31	28.5	27
Climbing-Aerobic						
30 min 6% climb, 80% max HR, feet per hr	2,700	3,000	3,400	3,700	4,000	4,250
30 min 8% climb, 80% max HR, feet per hr	3,000	3,300	3,800	4,100	4,400	4,700
30 min 6% climb, max, feet per hr	3,000	3,300	3,800	4,100	4,400	4,700
30 min 8% climb, max, feet per hr	3,300	3,600	4,200	4,500	4,800	5,100
Anaerobic						
Anaerobic power 10 sec, watts/kg	10	12	14	16	18	20
Anaerobic power 10 sec, watts/70 kg (154 lb)	700	850	1,000	1,120	1,250	1,400
Torque, peak, crank, pound-inches	650	775	900	1,000	1,100	1,250
Anaerobic power 10 sec, X TT power	2.7	2.9	3.2	3.4	3.5	3.6
Anaerobic power 30 sec, peak						
Anaerobic power 30 sec, average						
200m time, fast track, seconds	15.0	14.0	12.5	11.5	11.0	10.5
1000m time, fast track	1:20	1:19	1:17	1:15	1:13	1:10

Table 38. Training and fitness standards for excellence. Masters men.
***Standard aero: Skinsuit, aero helmet, disc wheel, standard frame, clip-ons.**
Where absolute values are given, may assume 70-kilogram (154 pound) rider.

Masters Women

Age	60	50	40	30
Training				
Training years	>5	>10	>10	>10
Races per year. Mt bikers may half.	10	10	15	20
Annual hours	450	550	650	750
Workouts / week	5	5	6	6
Annual miles	6,000	7,000	8,000	10,500
Annual climbing, feet	230K	320K	400K	750K
Training weeks / year	38	40	40	42
Weekly volume, hours	12	14	16	18
Weekly volume, miles	160	175	200	250
Weekly climbing, feet. Big weeks will double	6,000	8,000	10,000	18,000
Fitness				
Anthropomorphic				
Percent body fat	<20%	<17%	<14%	<11%
Weight, pounds: (Inches > 60” X 4) +:	105	105	100	100
Neuromuscular—Leg Speed				
RPM, progressive, 60 second increments	120	125	130	135
RPM, progressive, 30 second increments	130	135	140	150
RPM, progressive, 15 second increments	140	145	155	165
Muscular				
ILTs 60 rpm, 3 min, watts/kg	2.5	2.8	3.1	3.4
ILTs 80 rpm, min	3	3	4	5
Aerobic				
Max				
VO_2 max, absolute, L/min, 55 kg (121 lb)	3.0	3.3	3.6	3.9
VO_2 max, mass scaled, ml/kg/min	55	60	65	70
Ramped max power, watts/kg	4.0	4.5	5.0	5.5

Masters Women (continued)

Age	60	50	40	30
Economy, watts/L/min	71	72	73	74
Max climbing rate (5 min), 6% grade, feet per hr	3,600	4,000	5,000	5,400
Max climbing rate (5 min), 8% grade, feet per hr	4,000	4,500	5,400	5,850
Flat or climbing TT power, watts/kg (% max)	2.4 (60)	2.8 (62)	3.2 (64)	3.9 (71)
Flat or climbing TT power, watts, 55 kg	135	155	175	215
Aerodynamic-Aerobic				
Flat TT VO_2, absolute, L/min, 55 kg (121 lb)	2.5	2.8	3.0	3.3
Flat TT VO_2, mass scaled, ml/kg/min	45	50	55	60
Flat TT time 20K, standard aero*	35	33	31	29
Flat TT 20K 80% max HR, or non-aero	38	35	33	31
Climbing-Aerobic				
30 min 6% climb, 80% max HR, feet per hr	2,700	3,000	3,400	3,700
30 min 8% climb, 80% max HR, feet per hr	3,000	3,300	3,800	4,100
30 min 6% climb, max, feet per hr	3,000	3,300	3,800	4,100
30 min 8% climb, max, feet per hr	3,300	3,600	4,200	4,500
Anaerobic				
Anaerobic power 10 sec, watts/kg	10	12	14	16
Anaerobic power 10 sec, watts/55 kg (121 lb)	550	660	770	880
Torque, peak, crank, pound-inches	500	600	700	800
Anaerobic power 10 sec, X TT power	2.7	2.9	3.2	3.4
Anaerobic power 30 sec, peak				
Anaerobic power 30 sec, average				
200m time, fast track, seconds	15.0	14.0	12.5	11.5
1000m time, fast track	1:20	1:19	1:17	1:15

Table 39. Training and fitness standards for excellence. Masters women.
***Standard aero: Skinsuit, aero helmet, disc wheel, standard frame, clip-ons.**
Where absolute values are given, may assume 55-kilogram (121 pound) rider.

Appendix B: Training Glossary

Aerobic—Using oxygen with a fuel source. Implied intensity is below anaerobic level. Implied level of work is low enough that the rate of fuel consumption can be maintained for relatively long periods, that the buildup of lactic acid is avoided, and exercise can be continued for prolonged periods.

Anaerobic—Without the presence of oxygen. Implies a high level of work intensity that can only be maintained for relatively short periods of time. A very short energy production system—that of creatine phosphate—can supply energy need for about 10 seconds without the production of lactic acid. Other anaerobic efforts result in high levels of lactic acid. Carbohydrate fuel consumption rates are very high.

Anaerobic-Endurance—The ability to maintain near-sprint speed for up to several minutes. Sometimes called speed-endurance. The ability to tolerate high lactic acid levels is implicit; maintaining high fuel consumption is limiting.

ATP—Adenosine triphosphate. A chemical in cells serving as an immediate source of energy.

Blow Up—Go out too fast and not be able to continue.

Bonk—The exhaustion point in endurance events related to depleted carbohydrates.

Cadence—Revolutions per minute of the legs.

Cardiovascular—Referring to the heart and blood vessels.

Creatine Phosphate—A chemical in cells that can briefly replenish ATP and thereby produce energy for very short (up to 10 seconds) events.

Drop—Ride faster and away from another rider or group.

Duration—Length of time spent performing an interval. If work is continuous, volume and duration are the same.

Endurance—Ability to last.

Energy—The capacity to perform work.

Ergogenic—Special substances or treatments used to improve physiological, psychological, or biomechanical function. They may include nutritional, pharmacological, or psychological approaches.

Fartlek—"Speed play," unstructured intervals.

Fast-Twitch—Muscle fiber type characterized by a fast response to nerve stimulation. This type of muscle fiber tends to be useful in strength or power activities such as sprinting. Also called Type II muscle fiber.

Fatigue—The inability to maintain a level of work.

Force the Pace—Go harder and increase the pace of the group.

Glucose—A simple sugar. Used by the body for energy.

Glycogen—A complex sugar. A form of storage energy in the body.

Government Ride—All-day ride of modest intensity with multiple breaks and lunch.

Hammer—Hard, sustained effort.

Hang On—To just manage to stay with the pack.

Intensity—Load or speed of work.

Interval—Period of work.

Interval Workout—Hard training efforts interspersed with recovery or relief periods. The length of the interval normally is from just a few seconds to several minutes. The length of the interval, intensity of effort, gear (or workload) and cadence emphasize different aspects of fitness. Short efforts at high workloads tend to emphasize fast-twitch muscle strength. Efforts of a few minutes emphasize speed-endurance. Longer intervals emphasize lactic acid tolerance.

Isolated Leg Training, ILT—Training technique of riding with one leg.

Jam—High-speed riding.

Jump—A short, quick burst of speed.

Kick—Final burst of speed.

Lactate Suffering Factor—A conceptual approach to understanding interval and other effort strategies.

Lactic Acid—A product of the body's metabolism. Normally the blood contains about than one millimole of lactic acid per liter. Efforts up to time-trial threshold may result in levels of four to ten millimoles per liter. Levels higher than this cannot be sustained for prolonged periods.

Lactic Acid Clearance—The ability to clear, or metabolize, lactic acid.

Lactic Acid Tolerance—The ability to tolerate high lactic acid levels.

Leg Speed—How fast one can turn the cranks.

Mash—To push a big gear.

Motorpace—To draft a motorized vehicle. Often employed as a training technique. According to the vehicular code, illegal in many areas. Special safety precautions are advised.

Muffin Ride—Non-competitive supportive ride of friends with a muffin or pastry stop as a destination.

Neurohormonal—Relating to the brain, nerves, and endocrine glands.

Neuromuscular—Relating to the connection that occurs between nerve and muscle. Often used in the context of coordination, leg speed, or skills.

Noodling—Easy or recovery riding.

Oxygen Debt—Amount of oxygen used by the body during a recovery period from a work or interval period that is in excess of that used without work.

Overtraining—Lack of fitness related to excessive intensity or duration of training. Mental or physical.

Paceline—Group of riders in a line, alternating turns pulling at the front and sitting in.

Peak—Good form, high physical fitness. Often the result of hard work combined with a period of good recovery.

Peloton—The main group of riders, the pack, field.

Periodization—Training different aspects of fitness at different periods of time.

Power—Work performed per unit of time.

Recovery—Period of training time when not working hard—rest or relative-rest period. Many athletes view training as work. Work is only part of the equation: TRAINING = WORK + RECOVERY.

Pull—To ride into the wind without the benefit of a draft.

Pull Off—To move over and allow another to pull.

Pull Through—To assume the lead and take the wind.

Repetitions—The number of times a task or interval is repeated.

Set—In training, a group of repetitions.

Shelled—Toasted. No pep left. Wasted.

Sit-In—To rest, not pulling or working, to draft.

Skill Workout—Workouts without intensity designed to acquire neuromuscular co-ordination skills or techniques.

Slow-Twitch—Muscle fiber type characterized by a slow response to nerve stimulation. This type of muscle fiber tends to be useful in endurance activities. Also called Type I muscle fiber.

Snap—The ability to accelerate quickly.

Specificity—Training principle that states you specifically improve those characteristics of fitness that you train.

Speed—Quickness, how fast one can go.

Speed-Endurance—Anaerobic endurance. The ability to maintain near-sprint speed for up to several minutes. The ability to tolerate high lactic acid levels is implicit.

Spin—Often used to mean high cadence, it more accurately refers to the fluidity or suppleness of the pedal stroke.

Sprint—Acceleration (and usually maintenance) of very high speed.

Spun-Out—Unable to increase cadence, spinning as fast as possible. Implies the need for a bigger gear.

Stationary Trainer—Training device that does not move. Rollers, Lifecycles, Turbo Trainers, Trax stands are all varieties of stationary trainers.

Strength—Force that can be applied. Physiologists sometimes define strength as 1-rep maximum—the maximum weight or force that a muscle can generate once. This is a fast-twitch, or anaerobic-muscle measure. Maximum muscle force has more to do with pure sprinting than any other cycling discipline.

Strength-Endurance—Slow-twitch muscle strength. Aerobic-muscle strength.

Surge—Moderate acceleration from one tempo to a faster tempo or threshold pace. Not as abrupt as a jump or attack.

Tempo—Pace. Normally implies moderately hard, steady riding or running below time-trial threshold or race pace.

Time-Trial Threshold—Maximum pace for efforts of 20 to 60 minutes in duration. Anaerobic threshold, lactic acid threshold, and ventilation thresholds, terms physiologists use, are all at lower levels.

Toast—Fried. Cooked. Well-done. Unable to ride any more.

Torque—Rotational force. Measured in pound-inches or newton-meters. Commonly measured at the crank or at the rear wheel. Power per pedal stroke x 85 = Crank torque in pound-inches.

Training Effect—The body's response and adaptation to physical demands.

Turbo Trainer—Brand name of a type of stationary trainer device.

Volume of Training—Total time of intense training. If training is continuous, volume and duration are the same.

VO_2 Max—The maximum rate of oxygen uptake a person can utilize to produce energy. Often scaled to body weight. A measure of the ability of muscles to use oxygen. An important determinant of fitness and success.

Watt—Unit of power measurement equivalent to one joule per second.

Wind-up—To accelerate up to speed. Less abrupt than a jump, or attack.

Appendix C: Formulae

The following are some favorite bicycling-specific formulae used in this book.

VO_2 Max

From a Graded Exercise (Ramped) Test

$VO_2 = 12 \times watts/kg + 3.3$

See page 12.

To estimate VO_2 max from power output in a ramped test, use the following formula:

VO_2 max = 12 x watts/kg + 3.3.[55]

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.

[55] Work in joules = power (Watts) x seconds.
One joule= 0.24 calories (cal).
Some Assumptions
Burning 1 mL of oxygen when using carbohydrate yields 5 calories.
The basal caloric requirement is about 1 kilocalorie per kg per hour.
The body is about 24% efficient in converting calories to leg power.
Reasoning
The caloric equivalent of VO_2 (1) equals the calories used for muscle (2) and basal metabolism (3).
(1) Calories used per minute = 5 x mL O_2 used per minute.
(2) As one joule is about 24% of a calorie and the body is about 24% efficient, in one minute, muscle work in calories = watts x 60.
(3) Basal metabolism uses 1 cal per gram per hour, or 16.7 cal per kg per minute.
(1) = (2) + (3)
mL O_2 / min x 5 = (Watts x 60 / min) + (16.7 x kg / min)
mL O_2 / min = W + 3.3 x kg
VO_2 max = W/kg x 12 + 3.3

From Climbing Rate

VO_2 max = 15 x feet/hr / 1,000

VO_2 max = 50 x meters/hr / 1,000

To estimate VO_2 max from climbing rate, use the following formula:

VO_2 max = 15 x feet/hr / 1,000.[56]

Test on a 6% to 8% grade, one to one-and-one-half miles, taking 5 to 10 minutes.

Determine climbing rate, in feet per hour. (Feet climbed, multiplied by 60, divided by time in minutes.)

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

To achieve this rate takes a VO_2 max of about 45 (15 x 3,000/1,000) milliliters of oxygen per kilogram per minute.

[56] Oxygen consumption during climbing will overcome (1) gravity of the rider, (2) gravity of the equipment, and (3) other resistances. (4) Oxygen consumption during a 5 to 10 minute test will be at a submaximal rate.
(1) Basic physics: meters/second x 9.8 = watts/kg.
From the power formula, VO_2 (mL O_2 / min) = watts/kg x 12.
To convert meters/second to thousands of feet/hour multiply by 11.81.
Therefore VO_2 = thousands of feet/hour x 9.8 x 12 / 11.81.
Therefore, to overcome gravity, it takes very nearly 10 mL/kg body weight/min for every 1,000 feet climbed per hour.
(2) The work to overcome gravity includes the rider weight + bike + clothes + accessories; however, VO_2 max is based on rider weight alone. This is an about 15% difference.
(3) Climbing a 7% grade, it takes a fudge factor of 20^{+}% to overcome mechanical bike friction, road resistance, and air resistance.
(4) VO_2 max is about 10^{+}% higher than the submaximal VO_2 sustained on a climb of 5 to 10 minutes.
Total: Therefore, add 50% to 10 to give the formula figure of 15.

Local Climb
Arnie's Torrey Pines, San Diego Formula
VO2 = 360 /time min

See page 12.

To estimate VO2 max from time up San Diego's Torrey Pines Road from the parking lot to the flashing lights (1.4 miles, 400 feet of climbing), use the following formula:

VO2 max = 360 / time in minutes.

For example: An 8-minute climb equates to a VO2 max of 45 milliliters of oxygen per kilogram per minutes.

Agreement with the climbing rate formula:[57]

VO2 max = 15 x thousand feet/hour.

400 feet in 8 minutes is a rate of 3,000 feet per hour.

15 x 3 = 45 mL/kg/min.

Agreement with the graded ramp test formula

400 feet in 8 minutes, 3,000 feet per hour, equates to 915 meters per hour, or 0.25 meters per second. Since meters per second x 10 = watts/kilogram, this rate equates to 2.5 watts per kilogram total weight to overcome gravity.

There is an additional roughly 20% required to overcome mechanical bike friction, road resistance, and air resistance.

Note that the watts/kilogram total weight is the weights of rider + bike + clothes + accessories, generally about 15% more than rider weight alone.

Moreover, the effort of climbing for 5 to 10 minutes is below VO2 max. VO2 max is about 10% higher.

Therefore, add 45% to the 2.5 watts per kilogram to estimate VO2 max watts at 3.6 watts per kilogram.

Using the graded ramp test formula, 3.6 x 12 + 3.3 = 46 mL/kg/min.

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

Power

From Climbing Rate
Power (watts/rider kg) = 1.12 x feet/hr / 1,000
Power (watts/rider kg) = 3.67 x meters/hr / 1,000
Power (watts) = 1.12 x feet/hr / 1,000 x rider weight (kg)
Power (watts) = 3.67 x meters/hr / 1,000 x rider weight (kg)

To estimate power from climbing rate, use the following formulae:

Power (watts/kg) = 1.12 x feet/hr / 1,000.[58]

Power (watts) = 1.12 x feet/hr / 1,000 x rider weight (kg).

Test on a 6% to 8% grade. Determine climbing rate, in feet per hour. (Feet climbed, multiplied by 60, divided by time in minutes.)

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

Power (watts/kg) = 1.12 x 3
= 3.36 watts per kilogram

For a 70-kilogram (154-pound) rider:

Power (watts) = 1.12 x 3 x 70
= 235 watts

Summary: A 154-pound rider generates about 235 watts to climb at a rate of 3,000 feet per hour.

[58] Power will overcome (1) gravity of the rider, (2) gravity of the equipment, and (3) other resistances.
(1) Basic physics: meters/second x 9.8 = watts/kg.
To convert meters/second to thousands of feet/hour multiply by 11.81.
Therefore power (watts/kg) = 9.8 / 11.81 = 0.83.
(2) The work to overcome gravity includes the rider weight + bike + clothes + accessories.
This is an about 15% higher than the weight of the rider alone.
(3) Climbing a 7% grade, it takes a fudge factor of 20^{+}% to overcome mechanical bike friction, road resistance, and air resistance.
Total: Therefore, add 35% to 0.83 to give the formula figure of 1.12.
The formulae will likely underestimate the power of light riders whose (a) equipment will generally amount to >15% of body weight, and (b) whose friction and resistance costs will generate a higher than 20% fudge factor.
The formulae will likely underestimate the power of professional riders whose ascent speed will generate higher than 20% fudge factors due to overcoming higher air resistance.

Cross-Validating the Numbers

On a continuous climb, wattage meters and altimeters or Google Earth/Street View can validate the estimate.

Alternatively, wattage and other downloads can be checked to see if the values recorded make common sense.

For example, here is a PowerTap download into the Cycling Peaks program of a Category 3 male rider's ascent up the South Grade of Mt. Palomar, CA.

The PowerTap manufacturer claims an accuracy of 2.5%.

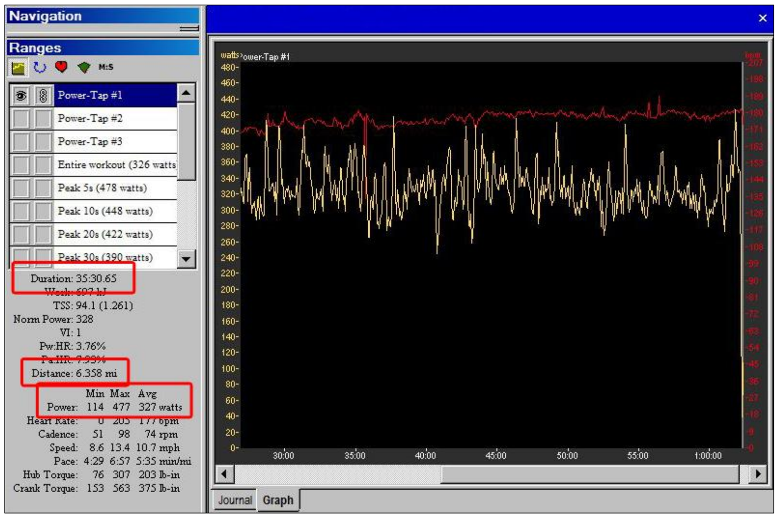


Figure 164. PowerTap download of climb. Red boxes: Average climbing power: 327 watts. Elapsed time: 35.30.65 minutes. Distance: 6.358 miles.

The program displays important data, including:

- Duration: 35:30.65 or 35.5 minutes
- Distance: 6.358 miles
- Average power 327 watts.

The recording is from the 41.4 milepost just after the first cattle crossing on South Grade to the direction sign just before the intersection with S7.

Zooming in on Google Earth, and placing the cursor at the start and finish will show the altitude.

Alternatively, where Google Street View is available, one can see the start and finish markers and read the elevation provided as part of the display, as in Figure 165 and Figure 166.

Here the starting elevation is 2,814 feet and the finishing elevation 5,237. The climb is therefore 2,423 feet.

Figure 165. Start of effort: Milepost 41.4, red ellipse. Google Street View displays the eye altitude, 2,814 feet, in the lower right-hand corner, red box.

Figure 166. End of the effort. Google Street View displays the eye altitude, 5,237 feet, in the lower right-hand corner (red box). Milepost 47.8, green, hard to read, is up the road about 100 feet on the right (red ellipse).

From Google Earth and Google Street View, the country mileposts indicate that the climb is about 100 feet short of 6.4 miles—that is 6.38 miles. That is close to the PowerTap recording of 6.35 miles.

From Google Street View we estimate the climb at 2,423 feet. Since the rider took 35.5 minutes, he climbed at a rate of 4,095 feet per hour.

The rider weighs 160 pounds, or 72.7 kilograms.

Plugging these values into the power formula:

Power (watts) = 1.12 x 4.095 x 72.7
= 333 watts

This is close to the measured value of 327 watts, and within the manufacturer's stated accuracy.

Calories Burned

See page 43.

To calculate calories burned riding, multiply average watts per hour x 3.6 x number of hours.

For example: If you average 150 watts per hour for two hours, you have burned 150 x 3.6 x 2 = 1,080 calories.

Crank Torque

Crank Torque From Wheel Torque

See page 62.

Crank torque = wheel torque x (chainring teeth / cog teeth).

Power Per Pedal Stroke

See page 55.

Torque is power per pedal stroke.

- To convert watts per pedal stroke to pound-inches, multiply by 85.[59]
- To convert watts per pedal stroke to newton-meters, multiply by 9.6 (or about 10).

Best Stationary Trainer Road Feel

See page 130.

The best stationary trainers mimic road feel by power resistance curves rising between the square and cube of speed.

Said differently, for speed to double, power requirements go up about six-fold.

[59] Torque (newton-meters)= Power (watts) **/** angular velocity (radians/second).
One newton-meter = 0.7376 foot-pounds
= 8.85 pound-inches
Cadence (rpm) = 60 **/** 2π radians/second
Therefore, power per pedal stroke units:
8.85 x 60 / 2π = 85

Appendix D: Hardware & Software

The following table summarizes features of downloadable hardware and software used throughout this book.

Other rider favorites, not used in this book include:

- The Cateye Astrale 8. It is an inexpensive computer that displays cadence. It is not downloadable.
- The Ciclo Sport HAC4. It has an altimeter. It imputes, but does not measure power. (It is inaccurate in measuring power.)
- The Garmin 205. It computes altitude gain from GPS data and is inaccurate. (The Garmin 305 uses a barometer. It is accurate.)

If power is measured, calories used can be easily calculated. Conversely, unless power is measured, calorie values are imputed estimates, and are not accurate.

Polar power sensors are inaccurate for stationary trainer workouts.

PowerTap currently supports PowerAgent software. This software does not allow the display of interval data. Older PowerTap Link 1.04 software or TrainingPeaks WKO+ software will display these values.

PowerTap and SRM measure, but do not display, torque with their own software. This data is accessible with third-party TrainingPeaks WKO+ software.

	Polar (HS)	PowerTap (HS)	SRM (HS)	Garmin (HS)	TrainingPeaks WKO+ (S)
Volume Measure					
Distance	✓ or option	✓	✓	✓	✓
Elapsed Time	✓	✓	✓	✓	✓
Altitude Gain	Sx25 Series	×	×	✓ Accurate with 305	✓
Kilojoules of Work	Option	✓	✓	×	✓
Intensity Measure					
Interval Distance		✓ on CPU	✓	✓	✓
Interval Time	✓	✓ on CPU	✓	✓	✓
Cadence	Option	✓ Accurate if crank sensor	✓	Option	✓
Heart Rate	✓	✓	✓	Option	✓
Speed	✓ or option	✓	✓	✓	✓
Climbing Rate	Viewable with CP	×	×	Viewable with CP	✓
Power	Option	✓	✓	×	✓
Torque	Viewable with CP	Viewable with CP	Viewable with CP	×	✓
Other Features					
Interval Data	Viewable with CP	Viewable with CP	✓	Viewable with CP	✓

Table 40. Hardware (H) and software (S) used in this book. TrainingPeaks WKO+ (CP) software will display all data collected by these hardware devices.

Appendix E: ABC Publications

The following subjects of this book are available as separate handouts from http://arniebakercycling.com. Additional material is sometimes provided in the handouts.

More than 100 additional handouts are available from http://arniebakercycling.com:

Handouts

- Aerobic Training
- Fitness Elements
- Focus & Breathing
- Heart-Rate-Based Training
- HIT™ Tips
- Isolated Leg Training
- Measuring Training Stress
- Overtraining
- Power-Based Training
- Recovery
- Stationary Training
- Training and Fitness Standards for Excellence
- Torque-Based Training
- Workout Too Hard—Dealing With Too Much Work

Enjoyed this Book?

Readers of this book have also frequently ordered the following available through http://arniebakercycling.com:

Books

- Altitude Climbing Endurance (ACE) Training for Cyclists
- Bicycling Medicine
- Nutrition for Sports
- Psychling Psychology—Mind Training for Cyclists
- Smart Cycling
- Strategy & Tactics for Cyclists

Handouts

- Bicycle Workout Series Handouts
  (Stationary Trainer Workouts)
- Endurance Sport Nutrition
- Heat & Cycling
- Pace Like a Lumberjack
- Pacing
- Training Logs
- Warm Ups for Racing
- Work of Breathing

Slide Shows

- Annual Plan—Planning Your Training Year
- Heart Rate Training
- Maltodextrin Nutrition
- Stationary Training